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FACULTY OF TECHNOLOGY
Energy and Environment Research Unit

SUSTAINABILITY ASSESSMENT OF FUTURE ENERGY STRATEGIES FOR MILTON KEYNES

by

Helena Titheridge

A thesis submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy

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Abstract

SUSTAINABILITY ASSESSMENT OF
FUTURE ENERGY STRATEGIES FOR
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Current patterns of energy use are unsustainable in the long-term. High dependence on the burning of fossil fuels cannot continue indefinitely. Sustainability Assessment is one way of including the wider environmental, social and economic impacts of energy use in policy-making. To date there is little experience of sustainability assessment being widely used to assess energy policies.

A sustainability assessment methodology was developed which combines an energy and emissions model (DREAM-city) with an impact database to appraise the impacts of a strategy, which are then presented in a matrix. The assessment methodology uses a process which follows similar steps to those typically used for environmental assessment and strategic environmental assessment (SEA), widely used by Local Authorities in other policy areas such as town-planning. A greater emphasis has been placed on the appraisal techniques and the presentation of the impacts than is usually the case with SEA techniques, where much of the literature to date has concentrated on the processes involved (Nilsson et al, 2004).

The assessment methodology was tested "in the laboratory" by comparing a series of different energy strategies that Milton Keynes could adopt. The methodology was then "field tested" by working closely with Milton Keynes Energy Agency to assess two different energy strategies.

The assessment methodology worked in the initial tests and was well received by Milton Keynes Energy Agency. The assessment is still open to some subjectivity due to necessity of summarising impacts tables to a level that is manageable. However, the

process is more likely to capture all known impacts consistently than techniques that start at the summary level. The methodology has increased transparency over standard strategic assessment techniques, as assumptions have to be laid out in detail at the energy modelling stage, but this is at the cost of increased complexity.

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INTRODUCTION

1.1 BACKGROUND

Current patterns of energy use are unsustainable in the long-term. Current energy use is highly dependent on the burning of fossil fuels. This results in a number of environmental impacts, including effects on local air quality and the emission of greenhouse gases which contribute towards global warming. WCED (1997) highlighted the challenge that current energy consumption patterns present for sustainable development, whilst chapter 28 of Agenda 21 (UNCED, 1993) emphasises the role of local authorities in achieving this. An increasing number of local authorities in the European Union are adopting a policy of reducing carbon dioxide emissions as a move towards slowing the rate of global warming. For example, Berlin is aiming at halving CO_2 emissions by 2010, as agreed by the Climate Alliance of European Cities (Kloft, 1995), while Leicester is aiming to reduce CO_2 emissions to 50% of 1990 levels by 2025 (Fleming, 1994).

In order to achieve these goals a number of programmes, plans and policies (PPPs) need to be implemented. However, there is usually a vast choice of measures available to the decision-maker which could contribute to the achievement of sustainable development policy objectives. It is difficult to choose the best combination of measures for a number of reasons. Firstly, PPPs adopted by a local authority to achieve the objectives set out in its energy policy may affect other aspects of the environment, society and the economy that are not part of the explicit aims of the policy. Secondly, many of these side effects may not be immediately obvious to the planners/decision makers. Traditional decision making processes do not encourage decision makers to take these into account explicitly. This makes it hard to justify any decision not made solely on the grounds of market cost. Thirdly, policy decisions made independently of one another may lead to confusion amongst those implementing the policies and cause clashes between policies, making their objectives difficult to achieve.

When choosing a selection of PPPs from perhaps a hundred or more possible options, local authorities and business do not have the resources to carry out a detailed analysis of every one. Many of the tools available to policy makers and planners to aid decision making are site specific, complex, and costly to apply; this makes them unsuitable for many local authority policy decisions. Other tools deal only with a limited number of environmental impacts, giving the planner a misleading picture, or deal with impacts at such a generalised level that it is difficult to identify differences between policies or avoid bias.

The European Commission recognises the importance of incorporating environmental considerations into the decision-making process. Under EC Directive 2001/42/EC a strategic environmental assessment of new energy policies, programmes and plans is now required. It can be argued that this does not go far enough, and that social and economic impacts of policies also need to be taken into consideration if sustainable development is to be achieved. To date there is little experience of sustainability assessment being widely used to assess energy policies.

1.1.1 Aims

The aim of the work described in this thesis is to develop a set of computer-based tools and an accompanying methodology that will help city decision makers look at the wider picture at all stages of the energy planning process and clarify and facilitate their decision-making processes. The methodology should also allow local authority decision-makers to demonstrate clearly the criteria upon which their decisions are based, and ensure a systematic evaluation and comparison of different strategies for progressing towards sustainability.

1.1.2 Objectives of the Research

1. To develop a methodology to facilitate the systematic assessment of different strategies for progressing towards sustainability, in terms of energy use. The methodology should be applicable not only to the city of Milton Keynes but to other cities.

2. To test this methodology using a series of scenarios describing different strategies for progressing towards sustainability, in terms of energy use and associated pollutant emissions, for Milton Keynes, over a period of several decades.

3. To further develop and refine the methodology through developing and evaluating a number of strategies in conjunction with Milton Keynes Energy Agency.

1.2 THESIS STRUCTURE

1.2.1 Energy Use and Sustainability

This chapter starts with a discussion of the definition and interpretation of the term sustainable development and its derivations. Particular reference is made to those themes that are relevant to energy production and consumption, such as resource depletion, the carrying capacity of the environment, quality of life and equity issues. The importance of energy consumption is highlighted and attention is drawn to the fact that all forms of energy supply will have some impact on society and the environment. The problem that faces society is how to select the strategies with the most acceptable impacts.

The chapter then goes on to discuss current global energy consumption and recent historical trends. Globally, there is a high dependence on non-renewable sources, in particular fossil fuels that are heavily polluting. Use of all fuels, with the exception of coal, has been increasing over the last decade. The rise in energy demand has been growing fastest in the newly emerging economies of the Asia-Pacific, Middle East and Africa, although these countries still only consume per capita one-tenth of that of the developed world. The damage caused by current patterns of consumption includes global warming, acid rain, air pollution, water pollution, health effects including an increase in respiratory diseases and cancers, and social issues such as inequity, poverty, security. Current energy patterns are unsustainable. Substantial changes are required soon in order to limit long-term damage to our environment.

1.2.2 Milton Keynes: A Sustainable City?

Milton Keynes has implemented a number of energy and environmental schemes over the last 30 years, particularly low energy housing schemes such as the Pennylands project, and demonstration exhibitions such as Homeworld, Energy World and more recently Futureworld. The Energy World exhibition, which consisted of a show village of 50 dwellings demonstrating energy efficiency, marked the launch of the Energy Park – a 120 hectare mixed-use site planned as a large-scale international demonstration of energy efficiency. Homes in the Energy World exhibition were built to score 7.5 out of 10 on the National Home Energy Rating (NHER) scheme. A house built to 1990 building regulations would achieve between 5.5 and 7.0 on the scale. This standard was later adopted city-wide and has been increased a number of times. All new homes are now required to achieve a score of 10.

Transport in Milton Keynes has long been a contentious issue – the high-speed grid network makes for fast journeys with relatively little congestion. The dispersed, low-density nature of Milton Keynes is likely to generate longer trips lengths and promote car use compared with a higher density city typical of the UK. Walk/cycle-ways, segregated from the roads, designed to encourage these modes, are under-used. A variety of different studies on travel patterns and transport energy consumption in Milton Keynes are discussed. Most are based on poor quality or inadequate data so it is difficult to draw any conclusions on how energy efficient transport in Milton Keynes really is.

Data on energy consumption in Milton Keynes estimated using the DREAM-city model is presented. The model output is compared with information on gas and electricity supply provided by the utilities. The city is then compared with the UK and other British cities. Milton Keynes consumes similar levels of energy per capita to the UK, but more than London and Newcastle. However, there are differences in the way in which transport energy consumption was calculated for the four cities (see Titheridge et al, 1996; Chell and Hutchinson, 1993; and Newcastle-upon-Tyne City Council, 1992).

1.2.3 The Potential for Change

This chapter discusses the variety of strategies available to Milton Keynes for reducing the environmental impacts of its energy consumption. The strategies discussed range from fuel switching, development of renewable sources, implementation of energy efficiency and improvements in energy management, and behavioural changes. The potential of each technology within the borough is discussed with reference to its costs and benefits.

1.2.4 Assessment Methodology

There are many motives for changing energy consumption patterns and no one obvious solution. Different policy options need to be compared on a consistent, transparent and objective basis. Methods currently available are inadequate for this task. Some are too labour- and data-intensive, others are too open to subjectivity and require use insufficient data to produce robust analyses. Yet other methodologies are too narrow, concentrating on only specific environmental criteria. Techniques like life cycle analysis are suitable for assessment of a technology rather than a policy. Many of the different methodologies currently available for energy policy assessment are compared and contrasted. It is concluded that energy models are the most suitable way of comparing a number of different policy strategies on a consistent basis. However, most energy models are limited to calculating levels of energy use and the associated emissions, and many only calculate carbon dioxide emissions. Other aspects of sustainable development need to be taken into account but many are difficult to incorporate into a model because a) the potential impacts are unquantified, b) the data is unreliable, or c) the data contains a great deal of uncertainty. In addition there is a problem of how to incorporate impacts with a low probability of occurrence.

A sustainability assessment methodology was developed to enable the scenarios to be assessed in terms of: (i) monetary costs; (ii) quantitative impacts, in terms of fossil fuel use and pollutant emissions; (iii) qualitative impacts; and (iv) other impacts that are identifiable but not assessable. The methodology combines an energy and emissions model (DREAM-city) with an impact database to appraise the impacts of a strategy, which are then presented in a matrix. The assessment methodology uses a process that follows similar steps to those typically used for environmental assessment and strategic environmental assessment, widely used by Local Authorities in other policy areas such as town-planning. The technique has been further developed to include economic and social impacts; and a greater emphasis has been placed on the appraisal techniques and the presentation of the impacts than is usually the case with SEA techniques, where much of the literature to date has concentrated on the processes involved (Nilsson et al, 2004).

1.2.5 Energy Strategies for Milton Keynes

The assessment methodology was tested "in the laboratory" by comparing a series of different energy strategies that the unitary authority could adopt. The strategies were designed to reflect a variety of different paths that Milton Keynes might implement. Each energy strategy involved a different emphasis on (a) energy conservation measures and efficiency improvements, (b) social changes, and (c) the use of cleaner fuels. Each also implied a different mixture of demand for electricity, heat and transport fuels. A single scenario is created for each strategy in preparation for the modelling part of the methodology. This chapter describes the strategies assessed and the assumptions made in creating the model scenarios.

The strategies assessed include:

(1) Current Trends Continued (CTC95) - this is based on current trends continuing;

(2) Fuel Switching (FSW), in this strategy every effort is made to use cleaner fuels: where possible gas is used instead of coal and oil, and renewables are used for electricity generation;

(3) Technical Fix (TFX), this strategy concentrates on improving energy efficiency. Those energy efficiency technologies are included that have a simple payback time of 5 years;

(4) Local Agenda 21 (LA21), which is based on the measures outlined in the Milton Keynes Agenda 21 document (MKEA, 1996). This contains a mix of energy efficiency and energy supply measures; and

(5) Green (GRN), which is the most radical of the five strategies. Those energy efficiency measures that repay their costs within the lifetime of the measure are included and there is also substantial fuel switching with renewables playing an important role.

1.2.6 Scenario Assessment

In this chapter the scenarios are assessed using the framework developed. The impacts of each scenario are presented and compared. The assessment finds that under the Current Trends Continued Scenario energy consumption continues to grow. The Fuel Switching scenario did little to cut the rate of growth. The Green scenario resulted in substantial reductions in CO2 emissions. The Technical Fix and Local Agenda 21 scenarios showed some reductions. Local emissions (except VOCs) were highest for the Current Trends Continued Scenario, and lowest for the Green Scenario. However, the Local Agenda 21 scenario showed increased carbon dioxide emissions compared with the Current Trends Continued Scenario. The Fuel switching scenario also showed slight increases in carbon dioxide emissions. Monetary costs were evaluated for a range of fuel prices and possible capital costs, using the methodology to be described in Chapter 5. Both the Fuel Switching Scenario and the Local Agenda 21 Scenario involved lower total expenditure than the Current Trends Continued Scenario. The Current Trends Continued Scenario had the highest fuel costs. The performance of the scenarios in terms of total monetary costs was dominated by capital costs. In terms of total monetary outlay, both the Fuel Switching and the Local Agenda 21 scenarios implied less outlay than the Current Trends Continued Scenario across the whole range of fuel prices and capital costs. However, if fuel prices are low and capital costs are low then the Green Scenario implied the lowest monetary outlay.

1.2.7 Methodology Testing

This chapter describes the "field testing" of the assessment framework. Working closely with Milton Keynes Energy Agency, two strategies were assessed: (i) a strategy aimed at meeting the UK government target of 10% electricity being generated from renewable sources by 2010 and (ii) a strategy for achieving zero growth in carbon dioxide emissions. In the process of developing the first strategy through the development of two scenarios (Renewables A and Renewables B), it was discovered that Renewables B met the requirements of zero growth in carbon dioxide emissions, so no further work was required to model and appraise this strategy. Thus, the two scenarios developed were:

Renewables A – a number of renewable energy schemes are implemented by the city, at a level which the city could easily absorb; and

Renewables B – about three times the amount of renewables installed under the Renewables A scenario are installed under this scenario. A proportion of these would have to be located outside the city.

These scenarios were modelled and assessed using the methodology developed. The chapter presents the process of working with Milton Keynes Energy Agency, the scenarios developed and the assessment results, as well as feedback from Milton Keynes Energy Agency regarding the assessment framework.

1.2.8 Conclusions

The assessment framework worked in the initial tests and was well received by Milton Keynes Energy Agency. The assessment is still open to some subjectivity due to necessity of summarising impacts tables to a manageable level. However, the process is more likely to capture all known impacts consistently than techniques that start at the summary level. The methodology has increased transparency over standard strategic assessment techniques, as assumptions have to be laid out in detail at the energy modelling stage, but this is at the cost of increased complexity.

1.3 Note on Timescale of Work

The initial methodology development and modelling work was carried out in 1995-7. The model used for this part of the work takes 1995 as its base. The methodology testing was carried out in 2000-1. As part of this process the model was updated and the scenarios assessed as part of the testing process use 2000 as the base year

Chapter Two

ENERGY USE AND SUSTAINABILITY

2.1 INTRODUCTION

This chapter provides an overview of the main issues surrounding energy use and sustainability. The debate surrounding the definition of sustainable development has been discussed and summarised endlessly in the literature (see for example Reid, 1995; Pearce *et al*, 1989), so no attempt is made here to repeat that discussion in depth. Instead the main points of the debate are highlighted and a few definitions of sustainable development are put forward to illustrate the general concept. This is followed by a more detailed discussion on what this means in terms of current and future energy use.

It should be noted that for the purposes of this discussion, the terms sustainable development and sustainability are treated as interchangeable.

2.2 WHAT IS SUSTAINABLE DEVELOPMENT?

The term sustainable development came to the fore in 1987 when it was used by the World Commission on Environment and Development in the so-called "Bruntland Report" (WCED, 1987). Although the concept had been used prior to this date, Mittler (2001) suggests that variations on the concept can be found as far back as the Seventeenth Century in literature on German forestry practices and even in medieval thought), but until the publication of the Bruntland report it had not received wide political or academic attention. Bruntland (WCED, 1987 p8) defined a sustainable society as one that: '*meets the needs of the present without compromising the ability of future generations to meet their own needs.*'

This sparked a wide debate over the meaning of the term: whether it was a feasible goal, whether it was a goal worth striving for, its uses and misuses by politicians and others – in particular, the adoption by many groups of a rather narrow interpretation, and the use of the concept to justify continued economic growth. There was also wide debate on the practicalities of implementing sustainable development policies. The problems highlighted included: too many different interpretations of the term; too many unknowns (particularly in relation to the global warming debate); problems of achieving inter- and intra- generational equity; and the balancing act required between seemingly different and conflicting goals. Jonathan Porritt (1993), a former Director of Friends of the Earth, argued that despite the debates over the definition of the term and its implementation, sustainable development was a useful term as it was generally acceptable to business, government and non-government organisations and sparked discussion and political movement in roughly the right direction.

In general the concepts covered by the various definitions of sustainable development include the idea of continued development with as little harm to the environment as possible. In many definitions, development is interpreted as economic growth, whilst in others the meaning of development has a broader interpretation and refers to a better quality of life. The concepts of intra- and inter- generational equity also appear widely.

Intra-generational equity calls for an equal distribution of wealth across the globe. Meadows (1992) defined a sustainable society as one which would not "*freeze into permanence the current inequitable patterns of distribution*". Wealth is not necessarily restricted to monetary wealth (usually measured as GDP per capita) but may include social, health and environmental indicators. See for example Jackson's social wealth index (Jackson and Marks, 1994), which attempts to capture all these elements in a single indicator, as well as capturing the equity of distribution of wealth within a country.

Inter-generational equity considers the preservation of resources or quality of life over the longer term, i.e. between generations. Those definitions of inter generational equity which focus on the "meeting of needs" of each generation rather than the preservation of resources at current levels e.g. Bruntland (WCED, 1997), at first glance at least, seem to be less limiting on the rate at which resources are used.

The term "future generations" of the Bruntland definition does not specify how far ahead one should consider. Taking this to its extreme there are an infinite number of future generations, with each entitled to a share of the finite resources such as natural gas, oil, and coal. This effectively means that the share of each finite resource that each generation can use is zero. Daly and Cobb (1990) attempt to reduce the ambiguity by specifying the following criteria that must be met if sustainability is to be reached:

1. Renewable resources are used at such a rate that they can regenerate;

2. Finite resources are used at a rate that does not exceed the rate at which renewable alternatives are developed;

3. Pollution emissions do not exceed the capacity of the environment to assimilate them.

This basically says that it is perfectly okay in his understanding of sustainable development to use finite resources as long as they are used at such a rate that renewable alternatives have been developed before the resource has been exhausted. However there are arguments against this. It is possible that some valuable uses of such resources have not yet been discovered and will only come to light after the bulk of the resource has gone. This argument is frequently applied to rain forest depletion and the loss of possible medicinal plants. On this topic Meadows *et al* (1972) said that a sustainable society is:

> *"one that can persist over generations, one that is far-seeing enough, flexible enough, and wise enough, not to undermine either its physical or its social systems of support."*

Pearce *et al* (1989) offers the counter-argument that future generations will be much wealthier in terms of man-made capital than the current generation (if economic growth continues) and therefore will be better able to solve problems or to find substitutes for resources. Pearce *et al* (*op. cit.*) suggest that seeking to maintain the combined level of natural and man-made capital is a more realistic goal and solves the intractable problem of how many generations one should take into account when allocating natural resources.

The way in which inter and intra generational equity are attained and the implications of achieving them for society is also highly dependent on the definition of "needs". Do you need a television? Do you need a car? These are questions a person with a good standard of living might ask while someone living below the poverty line may be questioning whether they really need heating. Thus one can pose the moral question of should those whose quality of life exceeds meeting the basic needs of food, water, health, warmth and shelter be expected to lower their current consumption to allow those living below the poverty line to achieve their basic needs? Another related idea, which is difficult to adequately address within the notion of sustainable development, is that not everyone in the world has the same needs.

Many politicians and environmentalists have latched on to the development part of the term as it conveys the idea of increasing wealth. However, development (wealth) is usually measured in economic terms - in Gross Domestic Product (GDP) to be precise, which does not take into account inequities in the distribution of wealth. Continued rise in GDP, it is argued, is not sustainable because of its vast reliance on resources. This is discussed in more detail in a variety of texts (see for example Whitelegg, 1993). Perhaps a better measure of development would be the quality of life, however, this is difficult to define and quantify. The IUCN, WWF and UNEP (1991) express this in their definition of sustainable development.

> *'..improving the quality of human life while living within the carrying capacity of the supporting ecosystems'*

Robert Goodwell (cited in Caldwell, 1994) of the World Bank on the other hand defines sustainability from an economic point of view as the "*maintenance of capital*". He identifies three forms of capital: human-made, human and natural. He offers three environmental sustainability rules or guidelines:

1. Output rule - waste emissions from a project should be within the assimilative capacity of the local environment to absorb, without unacceptable degradation of its future waste-absorptive capacity or other important services.

2. Input rule (renewables) - harvest rates of renewable resources' inputs should be within the regenerative capacity of the natural system that generates them.

3. Input rule (non-renewables) - depletion rates of non-renewables should be equal to the rate at which renewable substitutes are developed by human invention and investment. Part of the proceeds from liquidating non-renewables should be allocated to research in pursuit of sustainable substitutes.

He went on to say that the reserves of non-renewable resources might be kept for certain advantages that would not be easily obtainable through substitution, or in order to avoid the necessity of exploiting areas of environmental quality.

Munasinghe (1993) suggests that sustainability is not about the preservation of a particular set of resources but rather about having the resources to maintain resilience to shocks on the system. To achieve this resource needs may change, as the system evolves.

Flux (1994) highlights a key issue - which impacts are significant? What constitutes damage and what is a benefit? He cites the example of the beautiful landscape of Wensleydale formed by deforestation, mining and quarrying. Referring to Baker and Gregory (1994), he quotes

> *"Power stations along with other energy facilities have an impact on the environment. Whilst this is true, it is only a subset of the truth that all human activities have an impact on the environment"*

As already mentioned briefly, discussions on the 'sustainable' part of the term sustainable development tend to take rather a narrow definition, concentrating mainly on the environmental aspects of sustainability. This equally applies to the literature on energy and sustainable development. Sustainability has a number of other dimensions that apply to energy supply and use. Cohen (1992) lists the following:

a) Capacity to meet anticipated demand;

b) Security of supplies;

c) Resilience against temporary, localised supply disruptions;

d) Compatibility with reserves/resources;

e) Implied progress in energy economy and efficiency;

f) Viability and cost effectiveness of resource allocation;

g) Energy supply costs/technical feasibility;

h) Trade considerations including energy dependency;

i) Associated health, environmental and climatic hazards; and

j) Compliance with generally shared policy objectives, societal and economic trends and public concerns.

All of the above need to be taken into consideration when selecting an energy policy.

2.3 The Unsustainability of Current Energy Use

> *"Energy is essential to economic and social development and improved quality of life. Much of the world's energy, however, is currently produced and consumed in ways that could not be sustained if technology were to remain constant and if overall quantities were to increase substantially. The need to control atmospheric emissions of greenhouse and other gases and substances will increasingly need to be based on efficiency in energy production, transmission, distribution and consumption, and on growing reliance on environmentally sound energy systems, particularly new and renewable sources of energy. All energy sources will need to be used in ways that respect the atmosphere, human health, and the environment as a whole." (Quarrie, 1992 p97).*

This section intends to give a broad outline as to why current energy usage is unsustainable and why new policies need to be put in place at the international, national and local levels in order to reach a more sustainable pattern of energy consumption.

2.3.1 Current Energy Use World-Wide

World primary energy use currently stands at just under 9000 million tonnes of oil equivalent (Mtoe) (BP, 2001). Oil is the dominant fuel, accounting for 35% of total consumption. Natural Gas consumption accounts for a further 21%, and coal another 22%. The remainder split between nuclear at 7%, hydro-electricity at 2% and new renewables – 2% (BP, 2001). As can be seen from these figures, less than 5% of primary energy comes from renewable sources. However, it should be noted that these figures only include commercial energy. If non-commercial energy, mainly traditional biofuels, is included the renewables contribution is much larger. Foley (1987) estimated that these traditional fuels could amount to between 1.5 and 2.0 billion tonnes, equivalent to around 500 million tonnes of oil. Hall (1991) provides a somewhat higher estimate, suggesting non-commercial fuels account for as much as 14% of total consumption.

Over the last decade world primary energy consumption has increased by 11% over 1990 consumption. The use of all fuel types, with the exception of coal, which decreased by 4%, increased over this period (BP, 2001). The decrease in coal is largely explained by the collapse of the Soviet Union and restructuring in Europe of formally centrally planned economies, which were heavily reliant on coal. Coal consumption rose elsewhere. Oil use increased by 1% per annum, in line with the total rate of growth. Natural Gas use saw the largest rise – 22% over 1990 levels by 2000. Growth in Natural Gas consumption was fastest in the emerging economies. These figures exclude sources that are not traded commercially such as woodfuel, animal wastes and some renewables.

The consumption of energy is unevenly distributed across the globe. North America accounts for 28% of the world's energy consumption, Europe 21% and Asia-Pacific 27%, whilst Africa uses just 3% of total consumption (BP, 2001). Per capita energy consumption in North America is more than twice that of Europe and the former USSR and almost ten times that of the rest of the world. There has been no overall growth in per capita consumption over the last ten years, partly due to the collapse of the Soviet Union, leading to a substantial drop in energy consumption across this region. Total primary energy consumption fell by almost 35% between 1990 and 2000 in the former

USSR countries. Consumption in Europe rose by 4% over the same period, compared with increases of 18% in North America and 35% in the rest of the world.

A high proportion of primary energy consumption goes to generating electricity; 15,000 TWh were generated in 2000 worldwide (BP, 2001). Electricity consumption grew by just under 30% over the last decade. Only the former Soviet Union saw a decrease in electricity generation (-27%). The fastest rising regions were the Middle East (85%) and Asia Pacific (71%).

The combustion of oil, coal and gas produces a variety of emissions. Dust particles and other pollutants are also produced as a result of extraction, handling and transportation processes. The effects of these pollutants on the environment and on health are discussed below, along with societal problems associated with current patterns of energy production and consumption.

2.3.2 The Cost of Current Energy Consumption

2.3.2.1 Global Warming

Concern over global warming and increased concentrations of greenhouse gases (GHG) in the atmosphere has been growing since the early 1980s. This resulted in the setting up in 1988 of the International Panel on Climate Change (IPCC). The panel produced their first report in 1990, drawing together all the evidence for and against global warming and its impact on the environment and society. Since then a further two reports have been published – one in 1995 and the most recent in 2001.

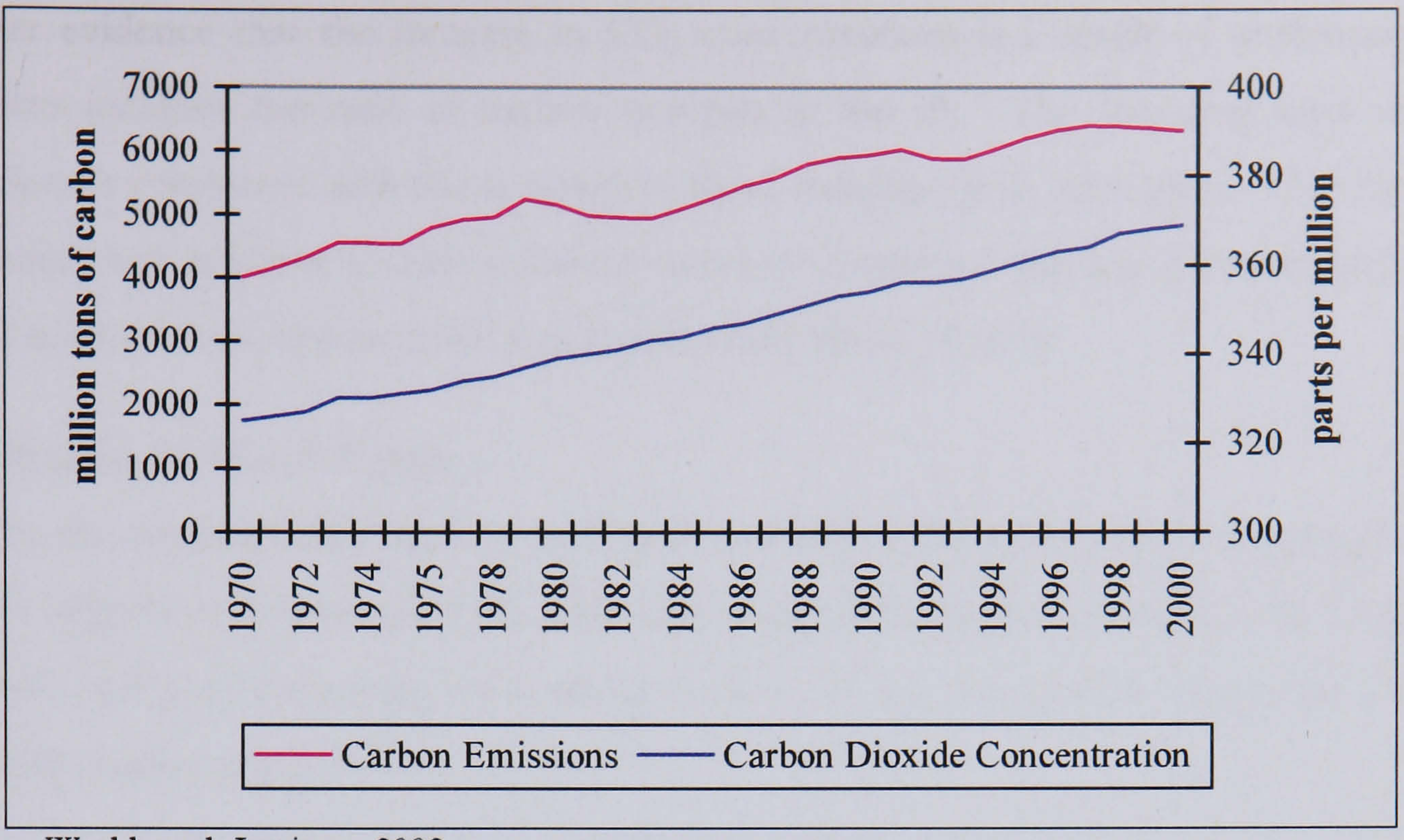
The gases giving cause for concern include carbon dioxide, chlorofluorocarbons (CFCs), Nitrogen dioxide (N2O), methane (CH4) and other hydro-carbons (NMHC). Non-carbon dioxide greenhouse gases such as chlorofluorocarbons, methane, and nitrous oxide have been major contributors to global warming in recent years. Water vapour is the most abundant greenhouse gas but human activity is not thought to affect global concentrations of this gas (U.S. Environmental Protection Agency, 2004). However, carbon dioxide is the most important greenhouse gas in terms of volume of anthropogenic emissions. The importance of carbon dioxide is likely to grow in the future as emissions of chlorofluorocarbons from refrigeration units and aerosols are curbed as a result of the 1987 Montreal protocol. Methane (CH4) and Nitrogen

Dioxide (N2O) are increasingly considered to be significant. Burning of fossil fuels for energy contributes to two-thirds of annual worldwide anthropogenic carbon-dioxide emissions.

The temperature of the Earth's surface is a result of a delicate balance between the amount of incoming short-wave radiation from the sun and the amount of radiation being lost to space. Of the incoming solar radiation approximately 30% is reflected back out to space, either scattered by the air, reflected off clouds, or off the surface. A further 20% is absorbed by clouds, water vapour in the air, dust particles and Ozone (O_3). The remaining 50% is absorbed by the Earth's surface, heating the land and sea. This is then re-emitted into the atmosphere over time as long-wave radiation. Similarly, radiation absorbed by clouds and the atmosphere is also emitted as long-wave radiation. Some of this long-wave radiation is lost to space; the rest is reabsorbed by the surface or by the water vapour and carbon dioxide in the air. As the concentrations of carbon dioxide, water vapour and other so-called greenhouse gases (because of their ability to absorb and re-emit energy) increase, an increased amount of heat can be absorbed and re-emitted back to earth; thus increasing the surface temperature and causing a raise in atmospheric temperatures.

Carbon Dioxide Emissions

Carbon dioxide concentration has been increasing since measurement began in 1958. Measurements of the levels of the carbon dioxide trapped in ice-core air pockets, suggest that carbon dioxide concentrations are now considerably higher than at any time in the last 160,000 years. The growth rate of carbon dioxide concentration is seasonal and highly variable from year to year and over longer timescales. Watson *et al* (1990) suggest that this variation is not "natural", that ice core bubbles show carbon dioxide concentrations varied only slightly over the last 1000 years – ten times less variation than observed in the last 150 years. The variation and rise in carbon dioxide concentrations are similar to those for emissions from fossil fuels and land use change (see Figure 2.1). However, the increase in carbon dioxide concentrations in the atmosphere is less than the rise in CO_2 emissions from anthropogenic sources. A proportion of the carbon dioxide emissions are taken up by natural sinks such as the ocean and the biosphere.



Source: Worldwatch Institute, 2002.

Figure 2.1: World carbon emissions from fossil fuel burning and atmospheric concentrations of carbon dioxide 1970-2000.

One of the uncertainties surrounding global warming is the size of these sinks – the extent to which they will continue to soak up carbon dioxide from the atmosphere. The amount taken up the oceans will depend on circulation currents in the ocean and its composition. These processes as yet are not well understood (IPCC, 2001a). The amount taken up by the biosphere could increase. In the context of global warming plants can be divided into two main groups – C3 and C4. For the former type, C3, current levels of carbon dioxide in the atmosphere are below that required for optimal photosynthesis. These plants, which include potatoes, wheat, rice and bananas, are likely to respond positively to a rise in CO_2 concentrations giving increased yields. This process is called CO_2 fertilisation. However, other factors besides carbon dioxide limit plant growth such as nutrient and water availability, so yields may not increase substantially. In addition, plants may adapt to the new levels of carbon dioxide in the atmosphere and yields decrease over time. Given the possibility of increased plant yields, particularly of many of the staple crops, some argue (see Idso, 1998) that carbon dioxide increases should be welcomed, particularly in the light of rising population. The latter type of plant, C4, will benefit little from carbon dioxide increases. This type includes maize.

Other evidence that the increase in CO_2 concentrations is a result of anthropogenic sources includes the ratio of carbon isotopes in the air. The changing ratio of the isotopes is consistent with those expected from anthropogenic emissions. There is also a south-north gradient to carbon dioxide concentrations and this gap is increasing in line with northern hemisphere fossil fuel combustion (IPCC, 2001b).

The Evidence for Global Warming

Given the evidence that the increased levels of carbon dioxide in the atmosphere are a result of increased carbon dioxide emissions from anthropogenic sources, what evidence is there that global warming is occurring, and if it is that it is due to changes in carbon dioxide concentrations?

One of the problems in detecting global warming is that there has been a lot of variation in global surface air temperatures over the last 140 years (since records began) (IPCC, 2001a). Although the warmest years have all occurred in the last 15 years, the rise may not be significant given the amount of variation (noise) observed. Since 1900, mean global temperature has risen by 0.5°C (op cit). Estimates vary depending on the methodology used to calculate the rise. Different baselines are used – the baseline is typically taken as the mean global surface air temperature over a number of years, but there is a wide variation in which years and how many years are used. In addition there are a lot of uncertainties in the data, due to improvements in instrumentation and changes in measurement standards. There is no internationally accepted way of calculating mean daily temperature. Overall uncertainties in the data have been put at as much as 0.15°C, resulting in warming of between 0.3°C and 0.6°C since the late 1900s (op cit).

The difference between minimum and maximum daily temperatures appears to be decreasing in many parts of the globe. Mitchell *et al* (1995) found that much of the rise in the mean global temperature could be attributed to increased night-time temperatures. They went on to suggest that this phenomenon was due to increased cloud cover and aerosols in the troposphere. Others have suggested that increased night-time temperatures are a result of urban expansion and the heat island effect (Drake 2000). Many meteorological stations were once in rural areas and are now within the urban area as a result of town expansion. The temperature differences between urban and rural areas can be as much as 6° and differences are at a maximum at night. IPCC (2001a) suggests this may account for 0.05°C of observed warming.

Given the problems of accuracy, consistency and noise with historical data on both temperature and carbon dioxide concentrations, it has proved extremely difficult to link the rise in mean global surface temperature with the rise in carbon dioxide in the atmosphere. It has been even more difficult to identify cause and effect. One of the few statistical analyses to be undertaken was that by Lane *et al* (1994). They found that during the 20^{th} century carbon dioxide concentrations and temperature anomalies data were highly correlated. However, it should be noted that correlation does not prove causality.

Objections have been raised to global warming on the grounds that that the principal radiation absorption band of carbon dioxide (15μm) is already saturated. Different molecules absorb different wavelengths (bands) of radiation. If enough of a substance is present all of the radiation of that wavelength will be absorbed. Once saturation of a bandwidth has occurred an increase in a substance will lead to no change in the amount of radiation trapped. Therefore, any increase in carbon dioxide concentrations in the atmosphere will not lead to an increase in the amount of solar radiation trapped in the atmosphere. However, CO_2 also absorbs radiation in the 14μm and 18μm bands and these wavelengths are not saturated, therefore more carbon dioxide will lead to more solar radiation being trapped in other parts of the spectrum.

The Marshall institute (1989) suggested that the Earth is about to enter another Little Ice Age and that global warming was needed to offset this; whilst others suggest that the current warming could just be continued recovery from the Little Ice Age, even though current temperatures in some areas are at their highest for thousands of years (Nicholls *et al*, 1996).

Lockwood *et al* (1999) suggest that up to half of the global warming so far observed could be due to changes in solar output. Prior to the 1930s most of the variation was due to solar output variations. From 1970 onwards, only a third of warming comes from the solar output variation. Other studies such as Damon and Perishykh (1999) agree.

Producing evidence of changes to other climatic variables has proved even more difficult. Less data is available on these. Nevertheless, various analyses suggest that there has been an increase in precipitation in the southern hemisphere and the mid-latitudes of the north hemisphere over the last few decades. This has been accompanied by a decrease in precipitation in the northern hemisphere sub-tropics (Drake, 2000).

Glaciers and small ice caps have been in general retreat worldwide for the last 100 years or more and the rate of retreat is accelerating (IPCC, 2001b) and sea levels have increased by 10-25 cm over the last 100 years, although the rate of rise is not accelerating (Drake, 2000). Arctic sea-ice seems to be melting; its extent has decreased by 3% per decade between 1978 and 1996, the sea ice has also thinned and the number of melt days during the summer months has increased. The extent of Antarctic sea-ice did not change significantly between 1973 and 1996, however, there is evidence that the extent of Antarctic sea-ice retreated by 2.8° latitude over the previous two decades (IPCC, 2001b). In more recent years a number of ice shelves have been lost, including the Larsen ice shelf which collapsed in 2002. Whether these incidents are due to global warming is not certain (British Antarctic Survey, 2004) and, no one is quite sure of the interaction between the polar ice sheets and global warming (IPCC, 2001b).

Extreme weather events have received a lot of press attention in recent years but as of yet there is little scientific evidence that either the number of extreme events is increasing or that this can be linked to global warming. Nicholls *et al* (1996) suggest that the number of tropical cyclones in the North Atlantic has decreased rather than increased. However, this assessment is debateable due to the nature of extreme events (i.e. rare) and difficulties in defining extremes. Other reports suggest that there are less extreme cold days, but no increase in the number of extreme hot days (Drake, 2000). Another aspect that has received a lot of press attention is the El Niño. The El Niño was previously documented as returning every 4-5 years. Since 1976/7 it has been returning every two years. As a result there have been changes in circulation and precipitation patterns. This may explain the decrease in hurricane activity observed by Nicholls *et al* (op. cit). Current El Niño southern oscillation behaviour has not been seen since records began 120 years ago. This does not necessarily mean new behaviour. El Niño southern oscillation events lead to high sea surface temperatures in large parts of the Pacific Ocean. It has been suggested that the increase in El Niño events has led to the increase in global mean surface temperatures, rather than global warming leading to an increase in El Niño events (Drake, op cit). Changes have also occurred to the North Atlantic oscillation but it is unclear how these relate to carbon dioxide increases.

The Impact of Global Warming

The IPCC looked at a variety of climate models. Using a number of different greenhouse gas emission scenarios and sensitivities to climate change, these models predicted for 2100 an increase in global mean surface temperature. In their third assessment report (IPCC, 2001a), the projections outlined in the 1995 assessment were revised upwards due to changes in predicted sulphur emissions and thus a reduction in the cooling effect of aerosols. Temperatures are projected to increase by 1.4° to 5.8° between 1990 and 2100, compared with the 1995 estimate of between 1°C and 4.5°C (Houghton et al, 1996). The predictions in the 1995 assessment were lower then those from the 1990 report, as the scenarios included the effect of aerosols such as sulphate particulates for the first time.

As well as improvements in the models for temperature rise, improvements have also been made, that allow the models to better predict the effects of global warming (IPCC, 2001a). The most recent models showed that even minor rises in mean global atmospheric temperature can have significant effects on the earth's climates. Land areas are predicted to warm more than the oceans and high latitudes are likely to see the largest increases in temperature. The effects of aerosols lessen the impact in the north hemisphere. Temperatures are likely to increase in late autumn and winter more than in the summer months, although there is no seasonal variation of the impact at low latitudes in the southern hemisphere or in the southern Antarctic Ocean. Over land the difference between day and night temperatures decreased in the majority of seasons and in most regions. There is likely to be an increase in precipitation globally; this affects the high latitudes in winter time the most, but also affects the mid-latitudes. The predicted effect on tropical rainfall varies between models. Sea level is projected to rise between 0.09 and 0.88 metres by 2100 due to thermal expansion of the oceans and melting of glaciers and ice caps (IPCC, 2001b). Regional scenarios contain large uncertainties. The models generally are too large-scale to model extreme weather events. Some models suggest more flooding events as well as more frequent and severe droughts.

The damage likely to be caused by the predicted climate changes is difficult to estimate due to the uncertainties of climate change. Different studies of the indirect impacts have produced different results from the IPCC scenarios (Drake 2000). In general, however, agricultural yields across the European Union are expected to increase whilst yields in North America decrease. Yields in many developing nations may also decrease, as these nations may not be able to afford the additional fertilisers needed to make the most of the CO_2 fertilisation effect. Precise increases in yield are difficult to predict and may not be as much as expected due to heat stresses, decreased soil moisture, increased soil erosion, more frequent droughts/floods, and possibly the increased prevalence of pests and diseases. The ratio of crops to weeds may increase as many weeds are of C4 type and will therefore not benefit as much as the crops from the CO_2 fertilisation effect.

The indirect impacts of global warming on health include increased mortality related to extreme temperatures. There is likely to be a decrease in the number of deaths in the mid northern latitudes related to extreme cold but an increase in deaths related to hot days more than offsets this reduction (IPCC, 2001b). Asthmatic episodes are also likely to increase. Tropical diseases such as Malaria, plague and typhus are likely to occur more in temperate zones, as mosquitoes and other carriers can survive further north. There will also be a number of side effects on health related to flooding and sea level rise.

The Earth's ecosystems will be affected. Many species will become extinct and even whole ecosystems with a resulting loss in biodiversity. The extent to which this occurs depends to some extent on the speed of warming and the degree of habitat isolation. Ecosystems will change and many specialist ecosystems will not be able to migrate as they depend on specific conditions such as soil type and geology. Some loss of biodiversity is inevitable.

The Need for Change

Taking the best guess from a number of different climate models, IPCC (Houghton *et al*, 1990) have calculated that a reduction of GHG emissions of over 60% of 1990 levels is needed to stabilised mean global surface temperature by 2100. In their most recent assessment (IPCC, 2001a) no figure was put on the reduction needed, but the report emphasised that a "*substantial reduction*" would be required.

Some economists arguing that it is cheaper to continue on the present course and react if and when impact of global warming is felt rather than pay now for new technology to combat the problem. For example, Singer (1992) does not accept the theory of global warming and warns against over hasty action that could have a detrimental economic impact. He argues against ruling out the use of fossil fuels and nuclear energy and the phasing in of carbon taxation immediately. Singer suggests a temporary increase in carbon emissions over the next few decades to allow developing countries time to install needed technology.

Governments however are taking the viewpoint that at least some action should be taken now and that this action should be multilateral. Thus, there have been a number of international agreements regarding greenhouse gases made through the United Nations Framework for Climate Change Convention (UNFCCC). The FCCC was adopted on May 9th 1992 and entered into force on March 20th 1994, 90 days after receipt of the 50th ratification. Nearly 200 countries ratified the voluntary agreement for Annex 1 countries (OECD, Eastern Europe and the former Soviet Union) to stabilize carbon emissions at 1990 by 2000. This agreement has been superseded by the Kyoto protocol, which was adopted in December 1997. The protocol aims to reduce global emissions from fossil fuels by 5% of 1990 levels by 2010. Each country within UNFCCC committed to different levels of reduction, the EU accepted an 8% reduction in 1990 emissions, whilst some countries are allowed to increase emissions in the short term. The protocol will come into force after 55 countries have ratified it, and with those having ratified the protocol accounting for 55% of greenhouse gas emissions. Currently, over 100 countries have ratified the agreement, accounting for 44.2% of industrial country carbon dioxide emissions. The Russian lower parliament voted on the 22nd October 2004 to ratify the protocol (Paton Walsh, 2004). The addition of

Russia to the list will allow the Kyoto protocol to come into effect. America and Australia have decided not to ratify the agreement.

2.3.2.2 Air Pollution

Burning of fossil fuels is the single greatest contributor to air pollution in the industrialised north (UNDP, 2002). A large proportion of emissions come from power stations with motor vehicles being a major contributor to poor air quality in urban areas. Globally, natural and man-made sources contribute in roughly equal parts to total emissions of sulphur oxides and nitrogen oxides (op cit). Natural sources include decomposition of organic matter, plankton and volcanic activity. Man-made sources include, as well as the burning of fossil fuels already mentioned, industrial processes such as the smelting of metal ores. In industrialised countries man-made emissions may contribute as much as 90% of total emissions (op cit). The burning of fossil fuels causes a variety of emissions of which sulphur dioxide, nitrogen-oxygen compounds, carbon monoxide, volatile organic compounds, particulates and ozone are the main contributors to air pollution. The precise quantities of each emitted depend on the type and temperature of combustion, the air: fuel ratio and the chemical composition of the fuel.

The consequences of air pollution can be divided into two main categories – poor air quality and acid deposition. The main impact of poor air quality is on our health, but can also affect the natural environment. The magnitude and nature of health problems generated are varied depending on the type and concentrations of pollutants but are mainly respiratory in nature. Acid deposition, commonly referred to as 'acid rain', tends to be transnational problem, whilst poor air quality is a localised problem. High levels of acid rain over time can have an accumulative affect on the acidity of soil and fresh water lakes, can increase the rate at which nutrients are leached from soil and erode stone, metal and other materials – thus damaging many of our buildings and other structures.

Acid Deposition

Sulphur dioxide is a result of combustion of sulphur rich fuels. Coal-fired power stations are the main producers of sulphur dioxide due to the high sulphur content of many coals. Some of this sulphur dioxide is further oxidised in the atmosphere to produce SO_3. The sulphur oxides then react with moisture in the air to form sulphurous acid (H_2SO_3) and sulphuric acid (H_2SO_4). The concentration of these acids is not sufficient to cause damage to plants and buildings directly but over time the accumulation of these acids in the environment can cause problems. This then falls to the ground as acid rain (alternatively it can be precipitated in the form of acid dew, fog, snow or hail).

The accumulation of acid in freshwater lakes and rivers was first noticed in Sweden. Swedish scientists found that that the sulphur dioxide emissions produced by Sweden were insufficient to explain the acidity levels. It was consequently demonstrated that much of the sulphur dioxide deposited in the country had been transported from heavily industrialised areas – in particular, the United Kingdom and Central Europe. The long-range transportation of sulphur dioxide was, ironically, aided by the tall chimney stacks commonly used to alleviate local air problems. An OECD study which published its results in 1977 drew similar conclusions for Finland, Norway, Austria and Switzerland (Hanf, 2000). As a result of increasing acidity of freshwater lakes, scientists have noted considerable reductions in fish populations. Schofield (1976) noted that salmon populations in a number of rivers in southern Norway had been in decline since the early 1900s. He noted that massive fish kills of salmon and trout had periodically been reported usually in association with spring snowmelts or heavy autumn rains. Similar devastation to fish populations has been reported in Sweden and Canada. There are a variety of ways in which increased acidity of lakes and rivers has helped ravage fish populations – one of these is aluminium poisoning. All soils contain large amounts of aluminium. This is normally insoluble but the sulphate ion helps breakdown the complex compounds that bind the aluminium, allowing it to be washed into streams. There it affects the operation of the fish's gills causing mucus to be secreted that eventually blocks the gills, reducing the amount of oxygen that reaches the blood.

The first sign of forest damage from acid rain was noticed in the mid 1970s in the Alps when fir trees started to loose their needles. Around the same time West Germany noticed that Norway spruce trees showed similar signs of damage; their crowns were beginning to thin and their needles were turning brown as a result of acid waters leaching valuable nutrients from the soil. Sulphur dioxide also directly damages leaves by blocking the stomata, thus preventing photosynthesis. The stress caused to trees as a result of both these processes makes them more susceptible to attack from pests, fungi and environmental extremes such as severe frosts.

The impact of acid deposition on an area depends on the underlying geology. Limestone and other alkaline areas are less affected than areas with acid soils and insoluble rock as the limestone dissolves, acting as a buffer and neutralising the acid rain, reducing the accumulation in freshwater lakes and rivers.

An EC directive on permitted levels of sulphur dioxide emissions was one of the first instances of international co-operation regarding the environment. This agreement acknowledges responsibility of producer nations to prevent damage in other countries. The United States of America and Canada have also negotiated a similar agreement. More recently the EC introduced legislation to reduce the level of sulphur in petrol and diesel. Globally, emissions of sulphur dioxide per annum have been falling (UNDP, 2002). This reduction was helped by two factors, firstly a move towards gas as the preferred fuel for electricity generation and accompanying move away from sulphur heavy coals; secondly the ease with which sulphur dioxide emissions can be removed either during combustion process, using special combustion methods such as limestone injection multistage burners or fluidised bed combustion, or from the flue gases using scrubbers. A 50% to 90% reduction in sulphur dioxide emissions can be achieved using these techniques. Thus in Europe and North America the problem has largely been abated and the natural acid balance is beginning to return in Europe (UNDP, 2002). However, in Asia the problem of acidification is increasing, particularly in China where 73% of the energy consumed by the country is provided by coal (*ibid*) and it also may soon become a problem in South America and Africa, if fossil fuel use continues to increase in these regions (Boyle *et al*, 2004).

However, sulphur dioxide is not the only source of acid precipitation. Another constituent of acid rain is nitric acid (HNO_3), formed when nitrogen-oxygen compounds (NO_x) react with air. The production of nitrogen-oxygen compounds is a result of burning any fuel in air. As sulphur dioxide emissions are reduced, so the importance of nitrogen oxides increases. The main man-made source of nitrogen oxides is motor vehicles. Because the sources of nitrogen oxides are many and small, rather than few and large as with power stations producing sulphur dioxide, it is harder to reduce levels of these. Within the EC all new petrol (gasoline) vehicles must be fitted with three-way catalytic converters. These work by capturing unstable NO and NO_2 molecules and converting them to the more stable form NO_3, which is less likely to react with moisture in the air to form nitric acid. Unfortunately, motor vehicle use is rising globally and shows no signs of levelling off; OECD countries saw a 70% rise in road traffic vehicle-kilometres between 1980 and the mid 1990s (OECD 1999). Reductions in NO_x due to the use of catalytic converters may not be enough to counteract rising vehicle use. The effects are likely to be local rather than transnational, as the emissions are released at near ground level rather than from tall chimneystacks.

Ozone (O_3) is formed when sunlight reacts with some of the above pollutants. Near the ground, ozone in large quantities can affect the respiratory system. Ozone damages plants and materials such as rubber and textiles. It also acts as a catalyst for the formation of acid rain. Higher up in the atmosphere, ozone acts as an important filter of ultra-violet radiation, which can cause skin cancer.

Photochemical Smogs

If the acid sulphates remain in the atmosphere then sulphate particulates can then form, causing a yellow haze. This was a noticeable feature of the Smogs of London, which occurred frequently during the early half of the 20^{th} Century. The most notable one was the smog of 1952, which resulted in 4000 deaths over 5 days from respiratory and related diseases (Ramage, 1997). This is being seen less and less within the UK and Europe, following UK Clean Air Act of 1956 which banned the burning of coal on domestic fires in urban areas. EC legislation has tightening up on the level of sulphur in petrol and diesel, and on sulphur emissions from power stations. All helped by fact that it is possible to remove sulphur from fuel before combustion.

NO_x (nitrogen oxides) also affects people's respiratory system, damaging lung tissue and resulting in a reduction in lung function. It can also cause a swelling of tissues in the throat and upper respiratory tract, reduced oxygenation of body tissues and a build up of fluids in the lungs, and worsens existing problems such as asthma and bronchitis.

Volatile Organic Compounds are a mixture of different emissions, with a variety of problems associated with them. Some volatile organic compounds are a result of impurities in the fuel and are carcinogenic, others – hydrocarbons – are a result of incomplete combustion. The chemical smogs of Los Angeles are due to high levels of volatile organic compounds in the lower atmosphere (Ramage, 1997). In 1975 legislation was introduced in California, requiring all new cars to be fitted with catalytic converters in a bid to improve local air quality.

Other Health Impacts

Carbon monoxide (CO) is the result of incomplete combustion. Carbon monoxide acts as a poison. It is a highly volatile state and thus reacts easily with other chemicals. It has a suffocating effect on the individual; we are all aware of the dangers of exhaust fumes in unventilated spaces. The amount of carbon monoxide produced can be reduced through more efficient combustion and adjusting the air: fuel ratios. Catalytic converters fitted to motor vehicles trap carbon monoxide particles and help fix them with oxygen molecules to produce CO_2 and CO_3. Because of its relatively unstable state emissions from power stations is not a big problem.

Particulates are any part of the emissions that are solid particles. The larger particles are visible to the naked eye in the form of dust, smoke or soot. There is some evidence linking particulates to various respiratory diseases. Key sources of particulates and dust that are related to current patterns of energy consumption include fossil fuel combustion (including vehicles), handling and transportation of coal and dust swept by the wind from slag heaps created as a waste product of coal mining.

2.3.2.3 Water Pollution

Oil Spills

Tanker accidents occur regularly but few result in a major oil spillage (Clark, 2002). When oil spillage does occur the impact can be (but is not always the case) damaging. Perhaps the most memorable of the major oil spills in recent years occurred in 1989 when the Exxon Valdez hit rocks off the coast of Alaska. Thirty-nine thousand tonnes of oil were spilled, the resulting slick covered 10,000 square miles, killing sea otters, seals, killer whales and half a million sea birds (FOE, 1999). The area was still suffering over 10 years later, with population declines of herring and mussels – important food sources for sea birds, seals and Stellar sea lions. Local and commercial fishermen are also affected, with catches still below that of 1989. More recently, the grounding of the Sea Empress in 1996 resulted in over 70,000 tonnes of oil being spilt in the North Sea. Volunteers cleaned oil from 6900 sea birds that were covered in oil. These were just the ones washed ashore. It is estimated as many as 70,000 birds could have been killed as a result of this incident (RSPB, 2002). In December 1999, a corroded tanker bulkhead caused between 10-15,000 tonnes of heavy fuel oil to be spilled into the sea off the coast of Brittany. The slick affected 400 km of coastline and an estimated 300,000 birds, as well as affecting marine mammals and fish. Eight Special Protection Areas were affected (FOE, 2000). Oil damages the waterproofing of the birds wings, so they become wet and have to use more energy to stop from sinking. The oil also damages the parts of the feather that insulate the birds from the cold. Oil is also poisonous, so when the bird tries to clean the oil off its wings and swallows the oil it becomes ill. Finally, with all the extra energy involved in trying to stay afloat, warm and healthy the bird is left with little time and energy to hunt for food, so if it doesn't die from drowning, cold or poison it is likely to starve to death.

Major spillages are only a small part of the total marine oil pollution, thousands of minor spills from oil tankers, oilrigs and oil storage facilities also occur annually. In total tanker accidents account for around 2.5% of the world input of petroleum hydrocarbons to the sea each year (Clark, 2002). Other sources include oil washed into the ocean from heavily polluted rivers – rivers polluted with industrial waste and urban run-off (2.5%); oil from off-shore production processes (2.7%); and 3.9 % from natural seeps. The largest source of oil pollution, contributing to nearly 70% of the total world input each year, is from regular transportation operations - the bulk of which comes from transportation emissions (ibid). Another large part of this is a result of the need for oil tankers to be ballasted for their return journey; they use seawater for this. Significant quantities of oil are released in the process.

A survey organised by the RSPB in 2000, carried out over a week along the coast of Wales, found that 20% of sea birds were affected by oil (RSPB, 2001). Over 1.5 million tonnes of oil were spilled into the Niger Delta between 1982 and 1992 causing high levels of water pollution and the death of fish, mangroves and tropical forests. Most of this came from leaking pipelines (FOE, 2002). In 1998, a ruptured pipeline spilled over 40,000 barrels of oil off the coast of Nigeria, affecting 120 coastline communities (FOE, 1999).

Coal Mining Activities

For every 1 tonne of coal produced on average half a tonne of dirt is also produced (Gibson, 1980); this is often discarded close to the mine. Water running through these slag heaps can pick up a variety of pollutants. Mine waters pumped to the surface are also polluted, contaminated with dust particles, iron compounds, chlorides and sulphates. If not pumped to the surface and cleaned, this can result in polluted groundwater.

2.3.2.4 Radio-Active Contamination and Waste

Currently, over 30 countries produce power using nuclear generators and another six are proposing to build nuclear power reactors (WNA, 2004a). Nuclear power constitutes about 17% of the world's electricity consumption (UNDP, 2001). There are a number of issues surrounding the use of nuclear fuels to produce electricity – social (security and health) and environmental. There are strict codes of practice relating to the operation of nuclear power plants that govern the amount of radiation reactor personnel are exposed to. The International Commission on Radiological Protection (ICRP) issues recommendations on the maximum levels of exposure to radiation for both the general public and those working in the nuclear industry. Another international organisation – the International Atomic Energy Agency (IAEA) developed a set of codes in 1975 – the Nuclear Safety Standards' (NUSS) to try and reduce differences in standards of safety between nation states. However, neither system is binding.

Under normal operating conditions the risk of radiation poisoning to both the operators and the general public is negligible. Table 2.1 shows the annual radiation dose to the average person in Britain. Less than 1% of our annual dosage of radiation comes from the nuclear power industry, and that includes fallout from past nuclear weapons tests and residual fallout from Chernobyl (Ramage, 1997).

Source	Microsieverts
From Natural Sources	1200
Medical contributions [a]	400
Nuclear power industry [b]	7
Miscellaneous industrial	10
Fallout [c]	5
Total	1622

Source: Ramage, 1997

a Including x-rays and radio-active materials used diagnostically and for treatment

b Based on dose to the total population including workers in nuclear industries

c Fallout from past atmospheric nuclear weapons tests together with residual fallout from the Chernobyl accident

Table 2.1: Annual radiation dose to an average person in Britain

Reactor Accidents

The effects of a large-scale nuclear incident can be catastrophic. The most recent headline case, was that of Chernobyl in 1986, when a reactor exploded following a series of infringements of the official safety regulations (WCED, 1997). The incident occurred after 4,000 reactor-years. That is the total world-wide operational time of that type of reactor up to the point at which the Chernobyl accident occurred had amounted to approximately 4,000 years (Islam and Kindgren, 1986). However, this does not mean to say that the probability of another event of the size and type as that of Chernobyl is 1 in 4000 years of reactor operation. The frequencies of incidences of this type make it difficult to accurately assess the risk of reoccurrence.

Radio-Active Waste

Whilst improvements in safety can reduce the risk of radioactive contamination from both minor and major incidents at nuclear power plants, as yet no real solution has been found on how to treat radioactive waste. Radio-active waste can be broadly classified in several types – mine tailings, low level waste, intermediate level waste, high level waste including spent fuel. High-level waste and spent fuel in particular may well remain hazardous for many hundreds of years and no mechanism that the public feels is safe has been found for disposal of this waste. Twelve-thousand tonnes of spent fuel is produced each year; a quarter of this is reprocessed, the rest is stored for disposal. There is currently about 270,000 tonnes of spent fuel in storage (NWA, 2004b). Spent fuel reprocessing should reduce the quantities of high-level waste produced but the technology has not yet been widely implemented. Commercial reprocessing plant with capacity to treat 5000 tonnes per year is currently in operation. There is also concern about the safety of transporting spent fuel to the reprocessing plant, Japan currently ships its spent fuel to Europe for reprocessing; the recovered fuel is then returned to Japan (NWA, op. cit). Another concern is that poorer nations without the capacity to impose strict safeguards will become importers of nuclear waste in return for foreign currency.

2.3.2.5 Resource Depletion

Over 90% of the world's primary energy currently comes from finite resources (BP, 2001). During the 1970s, as a result of the "oil crisis", there was a lot of concern about the limited total reserves of fossil fuels (especially oil) and how quickly these were likely to be depleted. Estimates of the number of years left before each resource is depleted vary widely. There are several complications when estimating the rate of resource depletion.

Firstly, how much of the resource remains. Most estimates are based on proven reserves – this is the amount of fuel which is known about and which is proven to be technically and economically feasible to extract. There is no internationally agreed method for measuring this. Estimates using proved reserves depend on the current price of the fuel. In the United States of America this typically does not allow for additional oil reserves extracted through secondary and tertiary recovery techniques unless these have been shown to work locally (Mitchell et al, 2001). This provides for very conservative estimates. Currently, between 30% and 40% is actually extracted from a reservoir (op cit). As prime reserves (easily extractable) become depleted, it will become economical to use secondary and tertiary techniques to extract the remaining reserves. Improvements in technology are also changing what can economically be extracted.

Secondly, different assumptions are made about future demand. Future demand is dependent on fuel price, availability of alternative energy sources, changes to the structure of industry, economic growth, population growth and efficiency improvements.

Finally, there is the interaction between supply and demand to take into account. As prime reserves become depleted, secondary and tertiary extraction techniques will be employed and less economically attractive reservoirs will be mined. As prices rise and the fuel becomes scarce, the incentive to develop alternatives and lower grade fuels such as oil shales, tar sands and brown coal will increase. There is some debate as to whether these extraction techniques and alternatives can be brought on-stream quickly enough to adequately compensate for the expected rapid rate of decline in oil production (Bentley, 2002).

BP (2001) uses the ratio of proved reserves to current production (R/P) to illustrate the amount of each resource left. The R/P ratio for oil is around 40 years, for Natural Gas – 60 years and Coal – 230 years. The R/P ratio has gone up and down in the last 30 years. In the late 1970s the ratio for oil was less than 30 years, reaching a high in the mid 1990s of over 40 years. Proved reserves of Natural Gas have steadily been increasing. However, Bentley (2002) argues that use of R/P ratios over-simplifies the issues and goes on to suggest that oil production in almost all the major oil producing countries, except those in the Middle-East, has reached its peak, after which production steadily declines. This is a political risky situation, as if the Middle-East oil producing nations decide to limit the amount of oil they supply then a shortfall will be created that cannot be made up by increasing oil production from other countries. Even without any problems in the Middle-East, Bentley (op. cit.) suggests that world oil production will peak in the next 5 to 10 years as the Middle-East countries have little spare operating capacity and are possibly nearing their peak production rate (there is some uncertainty as to the size of the Middle-East reserves). Demand for petroleum is on the increase. The combined effect of increasing demand and decreasing supply will lead to a long-term global oil shortage (ibid).

2.3.2.6 Other Environmental Impacts

Habitats are under threat from a number of different energy supply related activities. Oil exploration threatens old growth frontier forests, coral reefs (including the Great Barrier Reef, which is already under threat from pollution and global warming) and mangroves. Habitats also subject to damage from leaks from overland oil pipelines. Construction of large-scale hydroelectric power stations involves the flooding of large areas of land as a result of reservoir formation behind the dam. For example, the Xingó hydro-electric project in Brazil inundated over 8000 hectares of land (Goldemberg, 1996). Opencast coal mining involves stripping the topsoil and up to 70 metres of rock away from vast areas (Foley, 1987). Opencast mines can cover vast areas. In the UK there is usually a requirement to restore the landscape back to its original condition once mining has finished, but elsewhere opencast (or strip-mining) has often left irretrievably damaged landscapes. Although not the primary cause of deforestation and desertification, the demand for woodfuel adds another strain on forests already under threat. For example 32% of desertification in Northern China, is a result of fuel collection (Goldemberg, 1996). UNDP (2001) disputes this saying that research has rarely found cases where fuel demand is a significant cause of deforestation and suggests that causation may well be the reverse with deforestation contributing to fuel poverty.

Dam construction from large-scale hydro can also alter water flow patterns that support important fisheries, as well as cutting off the supply of sediment necessary to maintain deltas and coastlines. Subsidence resulting from the collapse of deep-cast mines, in some cases the ground may sink as much as a metre (Foley, 1987), can also interfere drainage flows.

2.3.2.7 Social Impacts

Equity

The richest 20% of the world's population consume 80% of produce (GDP). The poorest 20% only consume 1% of GDP (Goldemberg, 1996). 2002 Gross National Income (GNI) per capita varied by a factor of just under 70 between high income and low income nations (World Bank, 2004). There are also significant disparities within countries.

Similar disparities exist in energy use. The richest 20% use 55% of the world's primary and final energy, whilst the poorest 20% use just 5%. North America per capita consumption of primary energy is double that of Europe and the former USSR, and ten times that of the rest of the world (BP, 2001). The richest also have greater access to "quality" energy, e.g. electricity. Nakinćenović *et al* (1998) describe quality energy as being flexible, convenient, on continuous supply, and easy to handle and store. Seventyfive percent of all electricity is consumed by the richest 20% whilst the poorest consume less than 3% (Goldemberg, 1996).

The energy intensity (energy consumed per unit of GDP) of nations also varies greatly. Except for former centrally planned regions, energy intensity is lower in countries with a high GDP. There are two reasons for this. Firstly, those with high incomes can afford more efficient end-use technologies and a greater turnover of technology capital. Secondly, the richest nations no longer depend on heavy industry to produce their wealth. In these nations a substantial proportion of GDP is generated by the tertiary sector. Many of the heavy industries, such as the steel industry, have transferred to developing nations.

Security

Energy sources are unevenly distributed across the globe, for example, 63% of the world's proved oil resources are in the Middle East, whilst large parts of sub-Saharan Africa have no energy sources other than wood fuel and animal wastes (BP, 2004). Many countries import large proportions of their energy, whilst others are net exporters. Few countries are self-sufficient in energy terms.

Mitchell *et al* (2001) refers to the triple threat of security – security from disruptions to day-to-day life, economic security and political security. These threats are irrespective of whether a nation is an energy importer or energy exporter.

The oil crisis of 1973 showed just how dependent many of the world's economies were on the few countries that formed the OPEC alliance. During the 1970s energy security was high on the political agenda. Since then, energy security has lost political importance. This is because the world energy market has diversified in several ways; the range of fuels has widened with the increasing use of natural gas and nuclear power, and the number of countries producing oil has increased (Mitchell *et al*, 2001). In addition, the energy market has become more competitive and there is more free trade movement. However, the collapse of the Soviet Union and recent political unrest in the Middle East and Asia has put energy security back on the geopolitical agenda, although not to the same extent as it was in the 1970s. The changes to the energy market means that no one region or cartel can control energy prices for long. This also means the suppliers political leverage is also lessened, reducing the value of a supplier withholding oil exports. In both economic and political terms, importers currently seem to have the upper hand. A global embargo on imports from a specific nation is likely to be much more devastating than a nation withholding exports. Economically, most energy exporters are highly dependent on energy export revenues to fund their non-energy imports; they need the sales of energy as much as the importers need low priced energy. Bentley (2002) points out that there is currently little spare oil production capacity in countries other than the Middle East to take up the slack should the Middle East nations decide to withhold exports (see also the earlier section on resource depletion). Whilst currently it may not be politically or economically in these countries interests to reduce output rates, this may change in the future.

Security from war is still an important issue. Not just war at the suppliers end, but war at the importers end, and the countries in between – especially in context of oil and natural gas pipelines. A high percentage of Russia's energy exports go through the Ukraine to Europe. If war broke out in the Ukraine, Russia would loose its major export route. In light of this, alternative routes and markets are currently being explored. Another recent security issue is the vulnerability of major energy installations such as nuclear power plants and oil refineries to terrorist attack. Although, how much this is an issue is uncertain.

The blockade in the UK by truck drivers of oil refineries and distribution centres in September 2000 in protest against high oil prices caused widespread disruption to everyday life. But it was the threat to the political security of the Government that caused Gordon Brown, the Chancellor of the Exchequer, to change fuel taxation policy.

A more recent example of how important the major economies view security of supply is the amount of military spending and the speed of reaction to the invasion of Kuwait by Iraq. The apparent threat to oil supplies was used to justify European and Japanese support of US actions. As the world's traditional energy sources (fossil fuels) become depleted (if they do – see section on resource depletion) political tensions over supply are likely to become more prevalent if the current dependence on oil continues.

Other Social Impacts

Other social impacts of current patterns of consumption include: several hundred deaths every year of energy extraction industry workers in work-related accidents such as explosions at the coalface, coalmine collapse, and accidents on oilrigs; and the displacement of communities associated with large-scale hydro schemes. As already mentioned under environmental impacts, large amounts of land are flooded upstream of the dam constructed to house the turbines. Often the best sites for constructing a hydroelectric power station are not completely uninhabited. Whole villages have to be relocated, as their homes are flooded as the reservoir is created.

2.4 The Future

Projections of future energy use if current trends continue vary depending on the assumptions used for population growth, economic growth and energy intensity changes. The World Energy Council (WEC) and the International Institute for Applied Systems Analysis (IIASA) suggest in their middle course scenario (Nakinćenović et al 1998) that energy consumption could rise to 20 Gtoe by 2050 compared with 9 Gtoe in 2000. In their high growth case, energy consumption rises to 25 Gtoe. Fossil fuels continue to dominate, making up at least 60% of primary energy use. Sulphur emissions in both cases are similar to those for 1990, whilst carbon emissions rise. IEA (1995) suggested in their reference case that energy consumption in 2010 would be 11.5 Gtoe.

Briefly, current trends in energy consumption are unsustainable for three main reasons:

1. Population growth

   The world's population has been growing at 1.5% per annum (World Bank, 2004) and is currently at 6.2 billion rising to 7 billion by 2015. Population is growing fastest in developing countries (1.7% per annum) – the regions that currently consume less energy and produce less product (GDP) but also have the most rapidly rising GDP and energy consumption (*ibid*). Even allowing for no change in GDP or energy consumption per capita, the projected population increases alone would result in a noticeable increase in world energy consumption. However, IPCC (2001c) suggest that world population will peak at the end of the 21st Century before going into decline.

2. Economic growth of developing countries

   Many developing countries have obtained high rates of economic growth over the past few decades, well above those achieved in most developed countries and these rates seem set to continue, as developing countries strive towards similar standards of living to those in OECD countries. These high rates of economic growth have been accompanied by high growth rates in energy consumption and high energy intensities.

   Nakinćenović *et al* (1998), amongst others, suggest that changes in energy intensity in developing countries will echo historical trends in OECD countries. This is because energy intensity levels in developing countries at present are similar to OECD countries when they had lower GDP. Others suggest that energy intensity in developing countries will peak at a lower level, than was the case for OECD countries as they will be able to take some advantage through technology leapfrogging and technology transfer. In either case, if disparities between developed and developing nations in terms of GDP are to disappear then it must be expected that energy consumption by developing countries will increase substantially before it can be reduced. It is also to be expected that developing countries will continue to use cheap energy sources in the short-term, even if this means fossil fuels combustion by inefficient and polluting methods.

3. The nature of environmental problems

   Many of the environmental problems mentioned above have a time-delayed response. They accumulate slowly over time and the damage is not evident until many years afterwards. This was the case for acidification of lakes and forests, and is the case for global warming. The IPCC (2001a) state that even if carbon dioxide emissions are drastically cut now there is little chance of stabilising mean global surface temperature before 2100. Much of the environmental damage resulting from energy consumption and production is irreparable.

Chapter Three

MILTON KEYNES – A SUSTAINABLE CITY?

3.1 INTRODUCTION

The new city of Milton Keynes lies within the unitary authority area[1] governed by Milton Keynes Council. The Milton Keynes Council area consists of a mixture of both rural and urban wards. Its 31,000 hectares provide jobs, amenities and homes for over 200,000 people living in 80,000 households (ONS, 2003). To the west and north, the Council Area borders with Northamptonshire, to the east it borders with Bedfordshire and to the south with Buckinghamshire. The A5, M1 and West Coast Main Line railway provide Milton Keynes with strong north-south transport links. Also running through the area is the Grand Union Canal. The urban areas include, as well as the new city of Milton Keynes, the older towns of Newport Pagnell and Olney. Wolverton, Bletchley and Stony Stratford have been incorporated into the new city.

Milton Keynes was designated a new town in 1967 to relieve the pressures of population growth that were occurring in the south of the county of Buckinghamshire, which was taking much of the spill-over from London. It was also thought that the new town would act as a regional growth area for the south east of the UK. The area designated for the new town included 3 small towns, 13 villages and many farms. The population of the area in 1967 was approximately 40,000. Milton Keynes was the last and largest of the 28 new towns that were built under the 1946 New Towns Act and is over 80% complete (MKC, 1999). The majority of the population of the Unitary Authority lives within the area designated for the new city – 170,000 people in the 2001 census of population (MKC, 2003). It was originally expected that the population of the city would be around 250,000 on completion. Milton Keynes has recently been identified as

[1] Local government structure as at 1 April 1998. Local government reorganisation, which took place on 1 April in each year between 1995 and 1998 involved only the non-metropolitan counties. Unitary Authorities (UA) have replaced the two-tier system of County Councils and Local Authority District Councils in parts of some shire counties and, in some instances, replacing the County completely. By legal definition all Unitary Authorities in England are counties. However, for many purposes the UAs are treated as districts.

a new growth centre by the UK Government (ODPM, 2003) with potential for up to 300,000 new jobs and 370,000 new homes to be created by 2031 in the Milton Keynes/South Midlands area.

The Milton Keynes Development Corporation (MKDC) was set up in 1967 to oversee development of the new town. It commissioned a panel of consultants to develop a master plan for the city, which was accepted as a basis for development a few years later. The plan included goals for the new town, and details for achieving those goals such as the layout of the main roads, the land use mix, location of facilities and services, and specifications for street furniture. The master plan specified that the new town would use a grid pattern of roads enclosing dispersed land uses, at approximately 1km intervals to provide fast, congestion-free routes across the city. The plan also specified a low density, low rise city with multiple centres and plenty of open spaces. At the time energy was cheap, employment plentiful and affluence increasing. It was thought that the future would demand accommodation for the motor car and increased living and leisure space. Importance was also placed on good landscape design. The grid roads are planted with a dense border of trees and shrubs on either side to reduce the visual and noise impacts of the roads. Industry, commerce, and residential housing are distributed throughout the city in an attempt to provide areas of employment, services and housing within walking distance of each other. The plan also incorporated a combined network for cyclist and pedestrians covering the whole city, using a combination of specially designated routes and back streets separated from the main grid roads.

The goals specified in the original master plan for the new town, were:

To provide:

- Opportunity and freedom of choice;
- Easy movement and access, good communications;
- Balance and variety;
- An attractive environment;
- A place where public awareness and participation is important;
- A place where resources are used efficiently and imaginatively.

The release of land for development was controlled by the Development Corporation to ensure the city developed in phases with the correct mix of amenities, jobs and housing types for the size of the town at each phase. The plan also restricted development in the rural areas, focusing most of the expansion to within the designated area of the new town

The Borough of Milton Keynes was formed in 1974 from the former authorities of Bletchley, Wolverton, Newport Pagnell and part of Winslow. Milton Keynes Borough Council adopted the goals and concepts of the city master plan in its local plan. The borough was made a unitary authority on 1st April 1997 and Milton Keynes Council was formed. In 1995, as part of the process to prepare a bid to become a unitary authority the borough council held a consultative exercise – 2020 Vision – which included a series of visioning workshops with key players in the borough, as well as a survey of borough residents. One of the outcomes of this consultative exercise was that the community thought that the goals of the original master plan still fitted with people's visions and that the goals reflected many of the ideas behind sustainable development. The new council developed the following vision statement, which it has since adopted as part of its strategic aims:

Working in partnership for the benefit of all peoples of Milton Keynes;

- Being – open, accessible and consultative;
- Tackling disadvantage and promoting equality;
- Promoting a healthy and sustainable environment;
- Ensuring service and excellence, efficiency and effectiveness.

Like many UK Local Authorities, Milton Keynes accepted the challenge, set forth in chapter 28 of the Global Action Plan for Sustainable Development (Agenda 21) produced at the Rio Earth Summit in June 1992, to promote sustainable development in its area through the production of a "Local Agenda 21" document (UNCED, 1992). The Milton Keynes Local Agenda 21 document was produced in 1997 with the backing of all the political parties and has formed the basis of local action. A revised Local Agenda 21 strategy was produced, and adopted by the Council, in 2002 (MKC, 2002a).

The Council Area appears to incorporate many features that favour long-term sustainability (e.g. its wealth of green spaces), although others appear unfavourable (e.g.

its over reliance on the motor car). However the overall pattern of energy use in the area is unlikely to be sustainable in the long-term for several reasons. Firstly, the dispersed, low-density nature of Milton Keynes leads to amenities being more widely separated than in other urban areas, thus increasing average journey lengths. In addition, bus operations in dispersed, low-density areas are not usually as economically viable as those in more densely populated centres due to fewer passengers per vehicle-mile. This generally results in reduced levels of service and hence people are more likely to use their cars (White, 1995). The situation in Milton Keynes is exacerbated by the lack of congestion and the difficulties of penetrating the housing areas (although with the introduction in the late 1980s of minibuses, the latter is less of a problem) (*ibid*).

Secondly, although the majority of buildings within Milton Keynes are less than 25 years old and by UK standards should have high standards of energy efficiency, the level of appliance ownership throughout Milton Keynes may be higher than for the rest of the UK. This is due to a combination of two reasons. Firstly, many new homes are fitted with appliances such as washing machines, dishwashers and tumble dryers as standard; whilst in older homes the uptake is slower as in many cases the fitting of these appliances has to wait until the kitchen is refitted. Secondly, Milton Keynes has a higher percentage of residents within socio-economic bands I and II than nationally. Households in this band on average own more appliances than any other socio-economic band (Central Statistics Office, 1994). In 1994 Milton Keynes had only 1.5 laundrettes per 100,000 of its population whilst Leicester, for example, had approximately 8 laundrettes per 100,000 people. This suggests that a greater proportion of households in Milton Keynes have access to their own washing machines.

3.2 Built Environment

Milton Keynes has a good record in implementing many innovative energy and environmental schemes over the last 20 years, particularly low energy housing schemes such as the Pennylands project, and demonstration exhibitions such as Homeworld, Energy World and more recently Futureworld. As a response to the 1973 energy crisis and growing fears of fuel shortages due to resource depletion, in 1976 Milton Keynes Development Corporation (MKDC) established an Energy Consultative Unit (MKDC, 1982). The Unit worked with MKDC and drew on researchers from the Energy Research Group at the Open University and the Built Environment Research Group at the Polytechnic of Central London (PCL). The Unit's brief was to provide advice on energy issues, investigate the effects of increasing fuel shortage on the development of Milton Keynes and to review current energy research. The Energy Consultative Unit also undertook its own research and developed a number of energy saving projects. The work of the Unit concentrated on domestic energy savings as this area was considered to have the most scope for cost-effective savings (*ibid*).

The first of the major exhibitions to be held in Milton Keynes - Homeworld – took place in 1981 and included 36 houses built by 20 developers (NEF, 1992). Homeworld was not strictly an energy project as the purpose of the exhibition was to demonstrate the latest ideas in housing design and technology. However, most of the developers addressed the issue of energy efficiency even though it was not directly part of the exhibition brief (*ibid*). The exhibition produced some very innovative housing which still stand out today, the most famous of these include the "Ideal Home" solar house, the "Autarkic" houses and the BBC Money Programme's "Futurehome 2000".

The second major exhibition to take place was Energy World. Energy World consisted of a show village of 50 dwellings demonstrating energy efficient homes. The exhibition was held in 1986 to mark the launch of the Energy Park. The Energy Park is a 300-acre (120 hectares) site in the west flank of Milton Keynes, containing housing, employment, community facilities and open space. The park was planned as a large-scale international demonstration of energy efficiency. The Energy Park road layout and landscaping were designed carefully so that developers could make the maximum use of building orientation and shelter provision in designing for energy efficiency.

All the dwellings in the Energy World exhibition had to score less than 120 on the Milton Keynes Energy Cost Index. On this scoring system a UK home built to the standards required by the building regulations in operation at the time of the exhibition would have scored around over 170 on the scale (Pilkington, 1986; MKDC, 1985). The Index was later refined to produce the National Home Energy Rating (NHER) Scheme[2]. Homes in the Energy World exhibition all had a rating of at least 7.5 (out of

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[2] National Home Energy Rating. A scheme for the energy assessment of domestic dwellings in the UK, administered by the National Energy Foundation. The ratings range from 0 to 10, with 0 being the worst and 10 the best and are based on the total energy-related running costs of the dwelling under standard occupancy per square metre of dwelling. The national average NHER is 4.3 (National Energy Foundation, 1992).

10) on the NHER scheme (NEF, 1992). A house built to the 1990 building regulations would achieve between 5.5 and 7.0 on the NHER scale. Many of the homes in the Energy Park achieved a score of 9.0 or above. The Energy World exhibition also included a wind and solar co-generation demonstration project. Nine houses were supplied with electricity generated by a wind turbine and an array of photovoltaic modules. Unfortunately the wind turbine had to be shut down in 1988 as the noise from the gearbox was disturbing residents (*ibid*).

Phase I of the Energy Park (which included the Energy World show village) was completed in 1988 and contained 600 dwellings (NEF, 1992). The houses built in this phase were conventional in design and used proven technology. All were built to a minimum of NHER 7.5. Phase I of the Energy Park was monitored by the National Energy Foundation (NEF). NEF found that the actual performance of the Energy Park housing on average was close to the design predictions (30% saving in total energy running costs compared with those expected from a home built to the Building Regulations in force at the time) (*ibid*). A joint study between NEF and the Building Research Establishment found that most of the differences between actual and predicted performance were due to occupancy factors such as required room temperature and heating hours.

In 1988 the Commission for New Towns (CNT) set a standard for all new homes within the designated area to be built to at least NHER 7.5. This standard has been increased several times since then and currently MKC are proposing, in the latest revisions to the local plan, that all new housing developments of 5 or more dwellings (or of greater than 1000m^2 gross floorspace for other types of development) will be required to achieve an energy rating equivalent to 10 on the NHER scale, to include an element of renewable energy production and either achieve carbon neutrality or contribute to a carbon fund (MKC, 2002b). A house built to the 1992 building regulations would have achieved between 7.0 and 7.5 on the scale. A report on the energy efficiency of the housing stock of Milton Keynes produced in compliance with the Home Energy Conservation Act of 1995 (MKBC, 1996) estimated that the housing stock (both public and private) in the Borough of Milton Keynes had an average NHER rating of 5.4. The national average NHER rating for housing stock is 4.3.

Unfortunately the rest of the Energy Park has not been as successful. Phase II consisted of the construction of a further 600 dwellings. For these a higher standard was set – the housing had to achieve a score of NHER 9.0 or higher. By May 1992 only a quarter of the dwellings had been built (NEF, 1992). Approximately a third of the site remains undeveloped, despite the Chiltern Hundreds Housing Association building 30 one- and two-bedroom houses within the Energy Park I in 1995 (Chilterns Hundred Housing Association, undated). The scheme consists of two rows of terraces linked by a glazed street. The street has a V-shaped glazed roof with vents that can be closed in winter to reduce heat loss and opened in summer to prevent over heating. The homes are well insulated and have an NHER rating of between 9.1 and 9.9 (and a SAP rating of between 86 and 93).

Phase III of the Energy Park was to consist of a small cluster of dwellings built along the edge of Furzton Lake, as well as commercial buildings and leisure facilities. A heat pump in the lake was to provide the buildings with heating and cooling. This phase has yet to be completed. Finally, the employment area of the Energy Park should on completion include over 100,000m^2 of industrial and commercial buildings. By May 1992 only 10% of the employment area had been developed. More recently, phase 1 construction within the Energy Park of the new headquarters for the National Energy Foundation was completed in 1999. The building is highly energy efficient and includes a small photovoltaic array and a wind powered light which illuminates the main entrance. Phase II was opened in February 2004 and includes a 13kW heat pump, a photovoltaic (PV) array and an evacuated tube solar collector for pre-heating hot water for the toilets and kitchen (NEF, 2004).

The third major exhibition – Future World – was held in 1994. Thirty-six new homes were on display, designed to give visitors to the exhibition an idea of the technology likely to be incorporated into our homes of the future but with some thought being given to "market reality" (RENEW, 1994). Many of the homes were built aiming at maximum NHER scores of 10. Included in the exhibition were some passive solar space heating systems and several properties included heat exchangers. The Stuart house included a glazed Trombe wall and the entry from Electricity Association Services was a series of houses fitted with air to water heat pumps. Several authors criticised the "lack of real innovation" in the Future World exhibition, including Boyle (1994) who stated that Future World was a "missed opportunity", and Oldham (1995) who felt that the designers had made very little real attempt to design the houses to maximise on passive solar gain and that many of the exhibitors showed little real understanding of how to design for passive solar gain.

As well as the major exhibitions, a number of innovative housing schemes have been developed within Milton Keynes. Sponsors of the projects have included MKDC, the EU and the then UK Department of Energy as well as private enterprises. Milton Keynes' first solar house – the Bradville Solar House – was completed in 1975 (Barac and Fodor, 1987). The Built Environment Research Group of the Polytechnic of Central London monitored the house for several years after it had been completed (MKDC, 1982). It was found (after some minor adjustments to the system) that the solar system contributed over 50% of the space and hot water heating requirements. Other projects include Solar Court in Great Linford, built in 1980 and consisting of 9 houses – 6 with active solar heating and 3 with conventional heating systems. Three houses were added later which included conservatories for passive solar gain and solar panels for preheating the hot water (NEF, 1992). The Pennylands project was the largest of the innovative housing schemes, consisting of 177 houses built between 1980 and 1981. Attention was paid to the layout of the site and the design of the homes to maximise passive solar gain (*ibid*). Other schemes include the Gifford Park Housing Co-operative site of 36 dwellings utilising passive solar gains and enhanced insulation, and four super-insulated, triple glazed houses on Calewen, Two Mile Ash. The Calewen houses also incorporated heat recovery from the ventilation air and were thought to be the first of their type in the UK (*ibid*).

Since the demise of MKDC in 1992, Milton Keynes Council and the Commission for New Towns (and most recently English Partnerships) have continued to encourage the construction of energy efficient housing with the sponsorship of schemes such as the Hastoe Thermie Housing at Lougton (built in 1993). The scheme comprised of 38 houses, 18 of which were built to Hastoe Housing Association standard specifications. The remainder incorporated a mixture of features and included some with above-building-regulation levels of insulation, optimised orientation for passive solar gain, heat recovery, solar preheating of domestic hot water and use of condensing boilers (Hastoe Housing Association, undated).

3.3 Transport

Transport in Milton Keynes has long been a contentious issue – the high-speed grid network with slip roads and roundabouts filtering traffic on and off to the local road networks within the estates makes for fast journeys with little congestion (at current traffic levels). Many of the estate roads were designed with no direct route from one edge of an estate to another, to discourage drivers from using the estates as short cuts during periods of peak traffic. The speeds on these roads are kept low with a mixture of traffic calming measures, such as speed ramps. The low speeds and low traffic levels making the estates, at least in theory, a safe environment for children.

The dispersed, low-density nature of Milton Keynes is likely to generate longer trip lengths and promote car use. Several studies have shown that low density settlements are likely to consume more energy, use less public transport and generate longer trip lengths than high density settlements (e.g. Newman and Kenworthy, 1989, 1991a, 1991b, and 1999; Ecotec, 1993). MKDC (Alston, 1991) argued, however, that the careful design of Milton Keynes minimised this effect, with basic facilities available on each estate, facilities requiring a larger catchment grouped between pairs of estates, district centres serving several estates providing supermarkets and finally the city centre providing regional facilities. They asserted that this hierarchical approach to facilities provision combined with walking and cycling provision, in the form of redways, encourages residents to walk for many of their needs and reduces average journey lengths.

Car ownership in Milton Keynes is high, with over 80% of households within the borough owning at least one car, compared with an average in the UK of 73% (ONS, 2003). The 2001 census of population shows that 71% of Milton Keynes' employed residents travel to work by car. Only 8.5% of employed residents travelled to work on public transport. This compares with average UK figures of 61.5% and 14.5% respectively. Roberts and Wood (1992, cited in Cervero, 1995) found that although the majority of Milton Keynes' employed residents work within the new town, most travel to work by car (approximately 75%). This results in one of the highest levels of vehicle kilometres travelled per capita per annum in Europe. Cervero (*ibid*) found that although the Mark III new towns (of which Milton Keynes is one) were highly self-contained and that the level of self-containment was being maintained as the towns matured, these are also the towns with the greatest provision for cars and are the most automobile dependent. He concludes that the level of self-containment must be attributed to the relative isolation of the Mark III new towns compared with the earlier British new towns such as Hatfield and Basildon.

MKDC commissioned a study from Milton Transport Management Ltd in 1990 (see also Alston, 1991) to compare levels of transport energy consumption and emissions in Milton Keynes with those of other UK urban areas (Milton Transport Management Ltd, 1991). The study found that the average distance travelled by car per capita per annum in Milton Keynes was 18% less than that for other UK urban areas, despite the greater number of car trips per capita per annum (16% above the average for UK urban areas). Average trip length by car was found to be 30% lower in Milton Keynes. The report goes on to estimate energy consumption. It suggests that the faster journey speeds mean that cars in Milton Keynes are running more efficiently. In addition the average journey by car involves less start/stops than in the average UK urban area. Accelerating and decelerating use more fuel than running at a steady speed, therefore lots of start/stops would increase fuel consumption on a journey. These savings combined with shorter distances lead MKDC to conclude that fuel consumption per km (and hence emissions as these ate closely related) are lower by over 30% than the UK urban average.

However, there are several criticisms of this work. Firstly, the study drew on a 1983 survey of Milton Keynes households. The town was far from being fully developed at this stage. Potter (1996, personal communication) argues that it takes time for travel patterns to mature and no real conclusions can be drawn until several years after the new town has been completed. Studies of the level of self-containment of the earlier new towns (Thomas, 1969; Cresswell and Thomas, 1972; and Breheny, 1990) have shown that the level of self-containment falls as the town matures. Lower levels of self-containment are likely to produce longer journey lengths. Secondly, no details are given as to the size and spatial coverage of the 1983 survey, making it difficult to draw conclusions on how representative the sample was or on the significance of the statistics. Thirdly, the report estimates fuel consumption on the basis of TRRL drive pattern data for an average journey speed of 40mph. This drive pattern data mimics typical drive patterns for this overall journey speed and is likely to assume more constant vehicle speeds than are typically experienced by Milton Keynes drivers. The grid road system with roundabouts every kilometre creates drive patterns with frequent acceleration and deceleration, most not leading to a measurable stop-start but involving, nevertheless, considerable loss of engine efficiency and thus increasing fuel consumption. Fourthly, the fuel savings from faster journey speeds are unlikely to be maintained. As the population of Milton Keynes increases combined with increasing car ownership and a continued growth in the distance travelled per person per year, congestion will increase as the amount of traffic reaches and exceeds capacity at junctions. As a result the number of stop-starts in a journey is likely to increase, leading to an increase in fuel consumption.

A more recent study, commissioned by TEST (Rawcliffe and Roberts, 1991), compared the travel patterns of Milton Keynes with Almere in the Netherlands, also a planned new town, in order to investigate the significance of urban form on travel patterns. Both towns are of a similar age, have similar target populations and have a fast rail link to the capital city. Through a specifically commissioned survey the TEST study found that 69% of trips in Milton Keynes were made by car compared with 43% in Almere. A more recent survey (1997) found that 85% of passenger trips made by Milton Keynes Borough residents and 84% made by residents of the city area were by car (MKC, 2000). The greatest differences in modal split between the two towns were for education and shopping trips. Neither town was found to have high levels of bus use despite Almere's "segregated bus lanes and its regular and integrated bus service" (Rawcliffe and Roberts, 1999, p311).

Banister *et al* (1997) used the TEST data to compare the energy consumption due to personal travel in Milton Keynes with a number of other UK urban areas, namely Leicester, Liverpool, Banbury, and Oxford. Banbury was found to have higher than expected energy consumption per trip (29.14 MJ/trip), whilst Milton Keynes did not emerge as being as energy-intensive as might have been expected (15.1 MJ/trip), falling in the middle of the range of the five UK cities.

As with the MKDC report (Milton Transport Management Ltd, 1991), the authors (Banister *et al*, 1997) use a fuel consumption figure based on standard UK drive patterns. However, it should be said that fuel consumption data does not exist which accurately reflects Milton Keynes drive patterns. Also nothing can be done about the fact that the data collected is unlikely to reflect the travel patterns of a mature, completed Milton Keynes. But these will limit the conclusions that can be drawn on the sustainability of Milton Keynes.

3.4 An Analysis of Current Energy Use

As already touched upon, data on the energy consumption of a large and varied area such as Milton Keynes is difficult to collect. Utility companies often only keep a record of the units of energy they have billed in a particular period and many of the units billed are estimated. Additionally, the sales or administration areas of the utilities often do not coincide with local authority boundaries. Recent proliferation in the number of companies selling electricity and gas following privatisation and deregulation of much of this sector, has made it increasingly time consuming and complex to collect data on the amount of energy supplied and the number of customers. The opening up of the markets has also had the effect that companies increasingly see this type of information as being commercially sensitive and therefore restrict access. It has proved particularly difficult to collect information on the amount of energy consumed in the transport sector, as no data is available on who purchases the fuel from each petrol station and thus where the fuel is consumed. It was therefore necessary, in assessing the present (and recent historic) patterns of energy demand and supply within the Milton Keynes Council Area, to use an energy model enabling energy consumption to be calculated using easily accessible data.

The energy model chosen – DREAM (Dynamic Regional Energy Assessment Model) – was originally developed by Godfrey Boyle in the Open University Energy & Environment Research Unit (EERU) to simulate the energy flows in the UK as a whole, and to create scenarios for future UK energy use (Boyle, 1996). It was then adapted for use in urban areas and titled "DREAM-City" (Titheridge and Boyle, 1996a and Titheridge *et al*, 1996). The model calculates energy demand across all sectors of a city – Domestic, Services, Industrial and Transport – based on parameters such as population, housing size and type, people per household, car ownership, the floor areas of buildings, appliance and plant efficiencies, the market shares of fuels, and indices of economic activity. The model takes into account seasonal variations, producing monthly demand and supply figures which can be broken down by fuel type, end-use and sub-sector (there are 11 sub-sectors in the Industrial and the Transport sectors, and 13 in the Services sector). DREAM also includes a supply-side sub-model. DREAM has been partially validated for the total UK energy supply and demand system for 1984 to 1988 (Boyle, 1996). DREAM-city has been applied to Leicester (Titheridge *et al*, 1996), Leicestershire (Leicestershire County Council, 1995) and Cerdanyola, part of the municipality of Barcelona (Boyle *et al*, 1994).

3.4.1 Milton Keynes Energy Model

The Milton Keynes Energy Model covers the whole of the Milton Keynes Council Area (formerly the borough of Milton Keynes). The model was set up using data for the years 1980 to 1995. The data required for the model parameters included, for example, the population of Milton Keynes, the number of households within the Council Area, the number of businesses and their size in terms of floor area. This data was collected from a variety of different sources. Where data was unavailable for the whole of this period, assumptions were made as to the changes that had occurred between data points. Where data for Milton Keynes was not available the next best alternative was used, i.e. county, regional, or national data. This was adjusted using whatever local data and knowledge were available. Details of the data sources and assumptions made are given in Chapter Six. For example, if data on a particular parameter was only available for one year for Milton Keynes and available for 15 years for the nation, then unless there was strong evidence to suggest that trends in Milton Keynes differed substantially from national trends, the national trend over the 15 years was imposed upon the Milton Keynes data. The collected data was entered into a database for ease of access and to allow speedy transferral of the information into the model. Many of the adjustments required to get the data into the correct format for the model were done within the database.

The supply-side sub-model was not used; this was because a large part of the energy supply system is beyond the remit of Local Authorities. Some aspects of the supply-side were modelled in detail, namely CHP, district heating and renewables, where communities can directly influence the amount of energy generated from each source and the technology used.

3.4.1.1 Service Sector

The services sector sub-model is divided into the following sub-sectors based on groups of classes within the 1992 standard industrial classification of economic activities.

1. Offices
2. Shops
3. Distribution (Warehouses etc.)
4. Commercial Services (Banks, Insurance etc.)

5. Leisure

6. Residential (Hotels etc.)

7. Personal Services (Laundrettes, Hairdressers etc.)

8. Government

9. Defence

10. Education

11. Health

12. Street Lighting

13. Catering (Restaurants etc.)

For each of the sub-sectors energy demand is calculated separately.

Energy demand for the services sector is calculated on the basis of floor area, amongst other factors. For each of the sub-sectors data is entered describing the consumption of energy due to cooking and for lighting and appliances in terms of specific energy consumption per unit of floor area. The calculation of the energy consumed due to water heating takes into account the temperature of the mains water which is fed into the system (this varies with the season), whilst the calculation of the energy consumed due to space heating and air-conditioning takes into consideration the required mean monthly internal temperature, the mean monthly external temperature and the rate at which heat is lost or gained through the walls, floors and roofs of the buildings. These figures are variable over time to take account of changing demand due to, for example, energy management measures being implemented or changes in working practice.

A fraction of each of the end uses (e.g. water heating, space heating) is then allocated to each of the following delivered energy sources: Gas, Oil, Electricity, Solid Fuel, or heat (from Combined Heat and Power (CHP) or District Heating schemes). At this point the efficiency of each method of conversion from fuel to final use is taken into account. The energy demands for each of the sub-sectors by fuel type are aggregated to produce a total monthly energy demand for the services sector; an annual energy demand total is also produced. This figure is then used to calculate primary energy and the amount of air-borne emissions produced due to the burning of fossil fuels. Model output can be either in the form of end-user demand or primary energy.

3.4.1.2 Domestic Sector

The domestic sector sub-model works in a similar way to the services sector. The energy consumption due to space heating is calculated in exactly the same way. However, the calculation of energy demand for water heating, cooking and lighting and appliances is based on the number of households within Milton Keynes, rather than the total floor area as was the case for the services sector. The hot water consumption calculations contain an additional component based on the number of individuals within a household. The number of households is determined using the population of Milton Keynes, the average number of people per household and the size of the transient population (mainly students and tourists). As with the services sector, all these parameters can vary over time. The use of air-cooling in the domestic sector sub-model is included in the calculation of the energy demand due to the use of appliances.

Spreadsheets have been developed to facilitate the calculation of the mean rate of heat loss through the fabric of the domestic buildings within Milton Keynes, per unit of floor area. The spreadsheets, which are based on the Building Research Establishment Domestic Energy Model (BREDEM) calculation method (Anderson, 1988) and are given in Titheridge (2004), calculate the rate of heat loss using the age and type of dwelling; the wall, roof, floor and window structure of the buildings; the amount and quality of insulation and draught proofing; and the existence of double or triple glazed windows.

3.4.1.3 Industrial Sector

The industrial sector sub-model is broken down into a number of sub-sectors, again these are based on the SIC(92) classification:

1. Textiles (including leather, clothing and footwear);
2. Engineering (electrical, mechanical and civil);
3. Food, Drink and Tobacco;
4. Ceramics and Bricks (including glass and cement);
5. Construction;
6. Paper and Printing (including production of cardboard);
7. Chemicals;

8. Metals (including iron and steel);

9. Rubber and Plastics;

10. Other (wood, furniture etc.);

11. Vehicle Manufacturing (including parts assembly).

For each of these sub-sectors the energy consumption is divided into two flows - energy consumption due to production, and energy consumption due to space heating. For simplicity and due to a lack of data on other types of energy demand within the industrial sector, it was assumed that the energy consumed for such purposes as, for example, the works canteen, lighting, running office appliances and hot water for the wash rooms were included with the energy due to production.

DREAM-MK calculates the energy consumption due to production using the following parameters: the energy consumed in producing a £ of output (measured in terms of gross value added); the output per month; and a deflator which takes into account inflation. The energy consumed due to space heating is calculated in much the same way as for the domestic and services sectors. A fraction of the total energy consumption for each sub-sector is then allocated to each of the fuel types.

3.4.1.4 Transport Sector

The transport model is divided into two sub-models: freight and personal travel. The latter is further divided into rural and urban households and then sub-divided into car owning and non-car owning households.

The personal travel sub-model calculates energy demand using data on the number of journeys made per person per month and the mean journey length, for each of the following purposes: shopping, work (including education) and leisure; and by each of these modes of transport: bus, train, and car. The total energy consumed for each mode of transport and each journey purpose is calculated using a load factor which takes into account the number of people travelling in each vehicle, a figure for vehicle fuel efficiency and a figure for the overall distance travelled, calculated from the mean journey length, the number of journeys per person and the population within each sub-sector (i.e. car-owning/non-car-owning). Journeys made by walking and cycling are assumed to involve no energy consumption.

The freight transport sub-model has ten sub-sectors based on NST Commodity Groups (Dft, 2003)

1. Agricultural products;
2. Foodstuffs;
3. Solid Fuel;
4. Petroleum;
5. Ores and metal waste;
6. Metal products;
7. Minerals and Building Materials;
8. Fertilisers;
9. Chemicals;
10. Machines and Miscellaneous.

Within each sub-sector the model calculates energy demand on the basis of the energy consumed to transport each tonne of product one kilometre by each mode of transport (boat, rail and road), the number of tonnes transported, and the number of kilometres travelled. The number of tonne-kilometres of travel generated within each sub-sector is assumed to be proportional to the output (adjusted for inflation) of the sub-sector. Air was not considered to be a significant factor in either personal travel or freight transport, as Milton Keynes has no airport.

3.4.2 Model Validation

Once all the data had been collected and entered into the model in the correct form, the model was run for each of the sectors. The results from the model simulation of the years 1980 to 1995 have been compared with the historical demand data supplied by the utilities. Some 'fine-tuning' -- adjusting parameters within their known ranges of uncertainty -- was necessary.

The model was partially validated by comparing the output from each of the sub-models for the Council Area of Milton Keynes with historical demand data supplied by the utilities. The historical (or 'actual') demand data for Milton Keynes was gathered with the help of East Midlands Electricity and British Gas Southern. In addition British Coal supplied data on the consumption of solid fuel in the non-domestic sector. Because the boundaries for East Midlands Electricity, British Gas Southern and the Council Area of Milton Keynes do not coincide, adjustments based on the consumption of energy units per customer were made to obtain figures for the Council Area.

In addition, during the historical period studied, changes in the regulation of the electricity and gas supply industries in the UK resulted in the establishment of new companies supplying electricity and gas. In particular, British Gas ceased to be the monopoly supplier to customers consuming in excess of 2,500 therms (73,245 kWh) of gas per year and East Midlands Electricity was similarly ceased to be the monopoly supplier of buildings with a peak electricity demand in excess of 100kW. These changes to the energy market meant that it was increasingly difficult to obtain the data necessary to validate the model as fully as originally anticipated. The extent to which the sub-models could be validated depended upon the availability and form of energy demand data.

Actual annual gas demand data was supplied by British Gas Southern for the whole of the Southern region for the years 1980 to 1995. The data was split into 3 categories of customer, which approximately corresponded with the domestic, services and industrial sub-models used in DREAM. British Gas Southern also supplied data on the gas sales to their Oxford District, of which MK is in the north-east corner. However, as no data on the number of British Gas Southern customers in the Oxford district could be obtained, it was not possible to utilise this data.

Actual annual electricity demand data was supplied by East Midlands Electricity (EME) for all of their customers for the period 1980 to 1995. Again the data was split into 3 sectors: domestic, commercial and industrial. In addition EME supplied data on the billed distribution of units and the number of customers within their Milton Keynes District for 1993. The EME Milton Keynes district includes the town of Buckingham and covers a wider area than the Council Area of Milton Keynes.

For each sector the average number of units of gas and electricity supplied per customer was calculated and then multiplied by the number of customers within the Council Area. For the domestic sector it was assumed that each household was equivalent to a customer. For electricity it was assumed that all households within the Council Area were connected, whilst a slightly lower figure of 85% was assumed for Gas, based on estimates provided by AGB (1992) for the East Midlands Electricity Board (EMEB) region. For the non-domestic sectors it was assumed that customers equated with 'hereditaments' (a unit of property used by the Inland Revenue for taxation purposes), and that it was likely that a similar percentage of hereditaments were supplied with gas as was the case in the domestic sector, thus 85% of hereditaments were supplied with gas.

Data on solid fuel supplied by British Coal to the Council Area of Milton Keynes was supplied by British Coal for the year ending March 1994. However, as much of the solid fuel is supplied by other companies and distributed from a wide variety of outlets this data was considered insufficient to be used in validation of the model.

Data on oil and petroleum products demand in Milton Keynes were not available. Therefore, it was not possible to validate the transport sector sub-model. However the model simulation of energy demand in the transport sector has been compared with UK transport energy demand, on the basis of residential population and the number of enterprises. The results of the comparison show that per capita demand in Milton Keynes is similar to that for the nation as a whole; this result is as good as can be expected considering the unique nature of transport patterns in Milton Keynes and the lack of local data.

3.4.2.1 Services Sector Model Validation

For annual delivered gas demand, discrepancies between the model simulation and the 'real' data ranged from -15% to 26% (Figure 3.1). However, all but two of the points for which a comparison could be made showed errors of between ±7%. As a result of privatisation and the opening up of the energy markets, more and more of the larger companies are purchasing their gas from suppliers other than British Gas. Figures on Gas sales from companies other than British Gas were not included in the data supplied by British Gas. This could account for the difference between the results of the model simulation and the British Gas data for annual gas consumption in 1993.

Discrepancies between modelled and 'real' annual delivered electricity demand ranged from -5% to 30%, whilst the majority of errors were between -5% and 16%. The largest errors occurred in the early years of the time period studied, reaching a minimum in 1991 before beginning to deviate again from the trend shown in the data supplied by EME (Figure 3.2). The exact cause of this has not been identified, but it is possible that there has been a large change in the use of electrical appliances, lighting and air conditioning in Milton Keynes compared with national usage trends. Unfortunately data on local trends in appliance usage was not available.

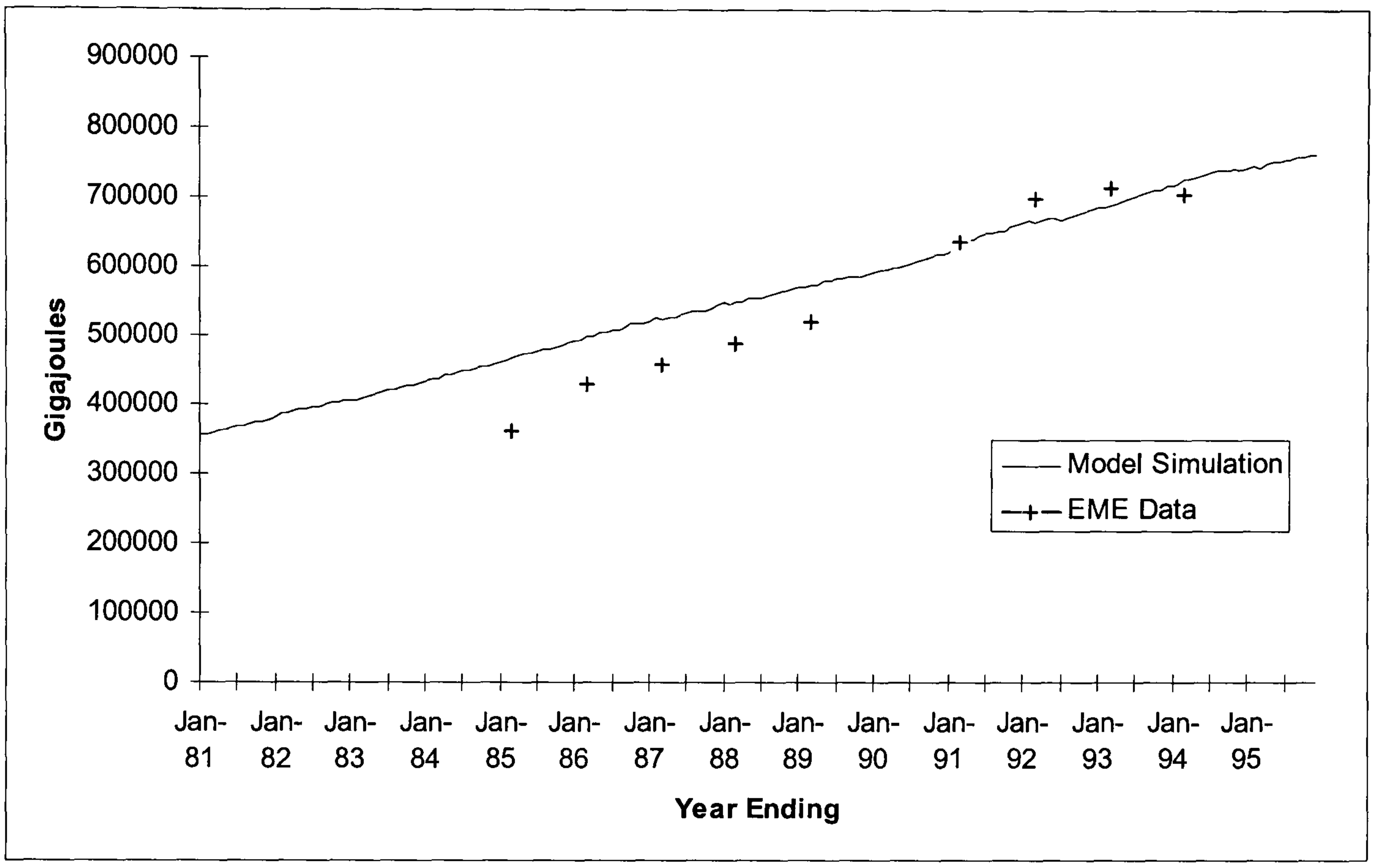

Figure 3.1: Comparison of Model Simulation of Services Sector Annual Rolling[3] Electricity Demand and Data on Actual Demand Supplied by East Midlands Electricity for the Same Period.

3.4.2.2 Domestic Sector Model Validation

Both East Midlands Electricity (EME) and British Gas provided energy demand data on a "units billed" basis for all sectors. Additionally, domestic customers are billed quarterly, and each month's data covers three months of electricity or gas consumption by one third of the domestic customers. Also many of the bills sent out to domestic customers are based on estimated readings rather than actual meter readings. British Gas now has a policy of only reading meters every 6 months for domestic customers, so approximately half of the "units billed" are estimates. Therefore, the demand data supplied by the utilities for the domestic sector is not a completely accurate measure of

[3] Annual rolling demand is calculated monthly, using 12 months worth of data. The 12 months used each time to calculate total demand are moved forward by a month, thus the annual rolling demand for January 1993 is the sum of demand for Jan 92-Jan 93; for February is the sum of demand for Feb 92 – Feb 93 and so on.

the actual demand of the Council Area and could be the source of some of the discrepancies between the model simulation and the actual demand data for both gas and electricity.

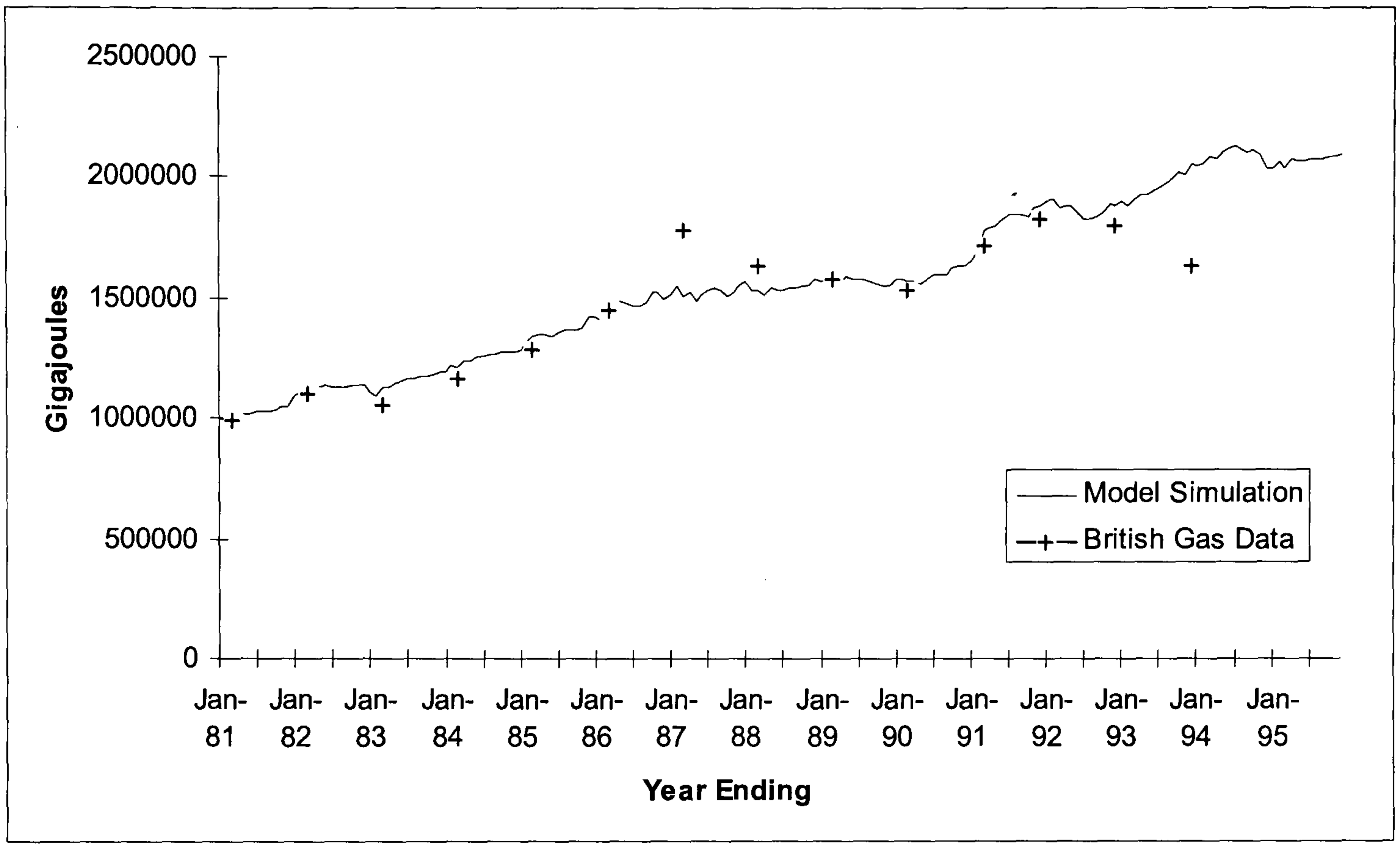

Figure 3.2: Comparison of the Model Simulation of Services Sector Annual Rolling Gas Demand and Data on Actual Demand Supplied by British Gas Southern for the Same Period.

For annual delivered gas demand, the overall discrepancy between the results of the model simulation and real annual demand data within the domestic sector was between 10.5% and -20.5% (Figure 3.3). The majority of the errors were between ±10%. Only two points were outside this range.

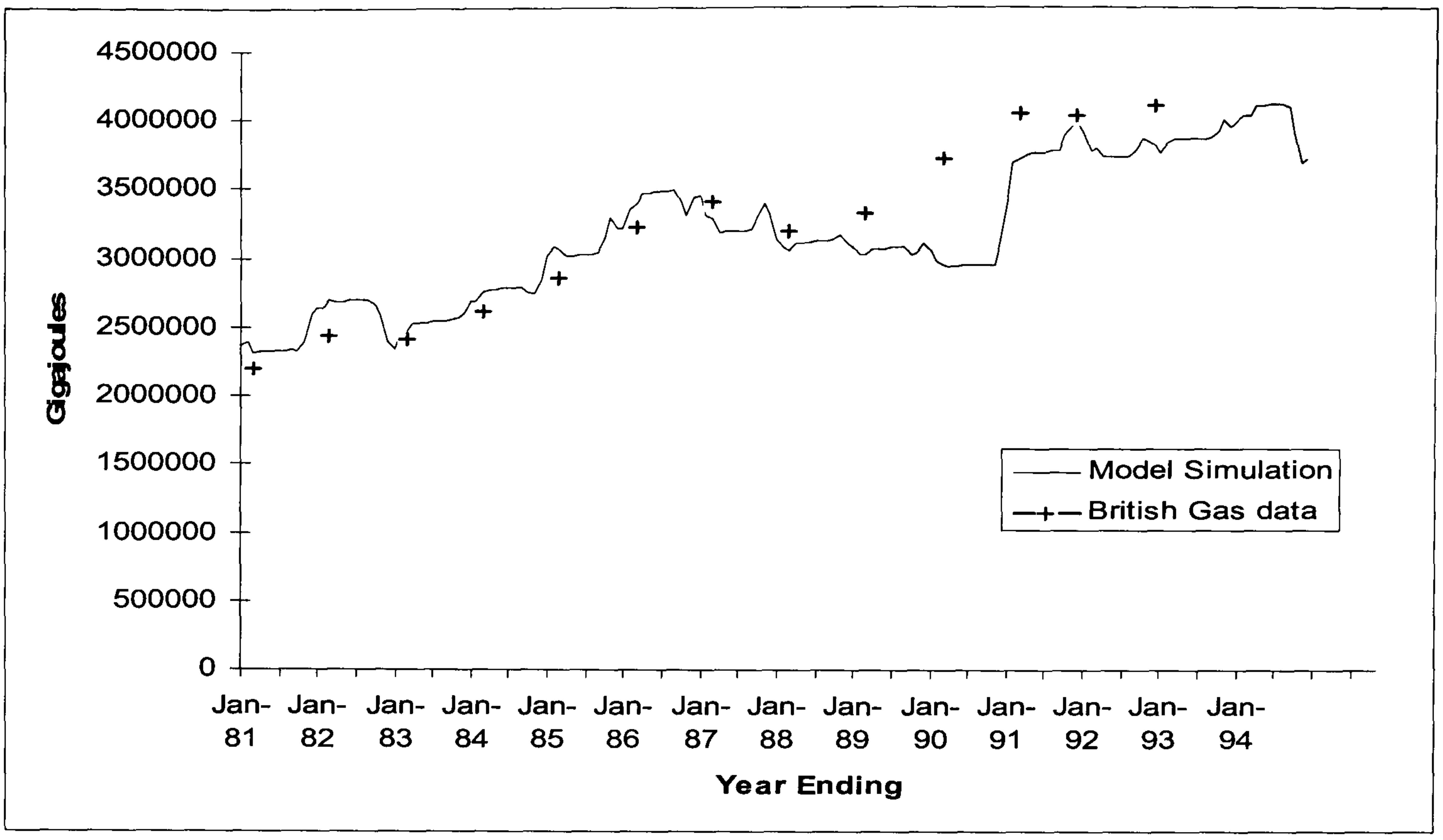

Figure 3.3: A Comparison of the Model Simulation of Domestic Sector Annual Rolling Gas Demand and Data on Actual Demand Supplied by British Gas Southern for the Same Period.

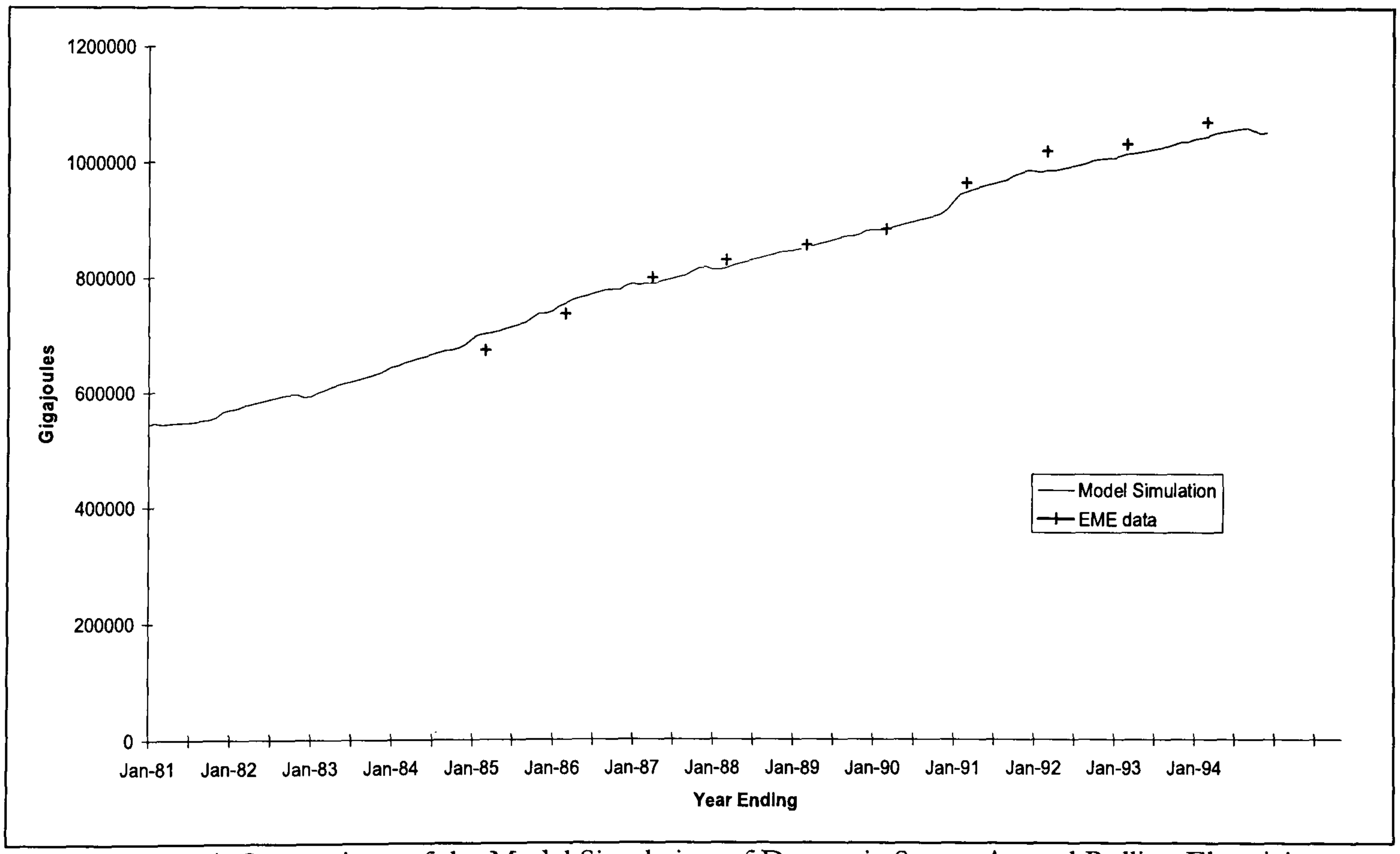

Figure 3.4: A Comparison of the Model Simulation of Domestic Sector Annual Rolling Electricity Demand and Data on Actual Demand Supplied by East Midlands Electricity for the Same Period.

The discrepancies between the model simulation of annual delivered electricity demand and the data supplied by EME were smaller, ranging between 5% and -4% with the majority of the errors between ±3% (Figure 3.4). Again only two points were outside this range.

3.4.2.3 Industrial Sector Model Validation

Discrepancies between the modelled and 'real' annual delivered gas demand in the industrial sub-sector showed errors of between ±30% (Figure 3.6). When compared with actual gas demand data for the sector, all except two of the data points were between ±17%. It is probable, however, that these errors are at least partially due to inaccuracies in the gas demand data, as the largest of the errors occurred in the years following the opening up of the gas market for customers consuming in excess of 2500 therms (73,245kWh) of gas per year.

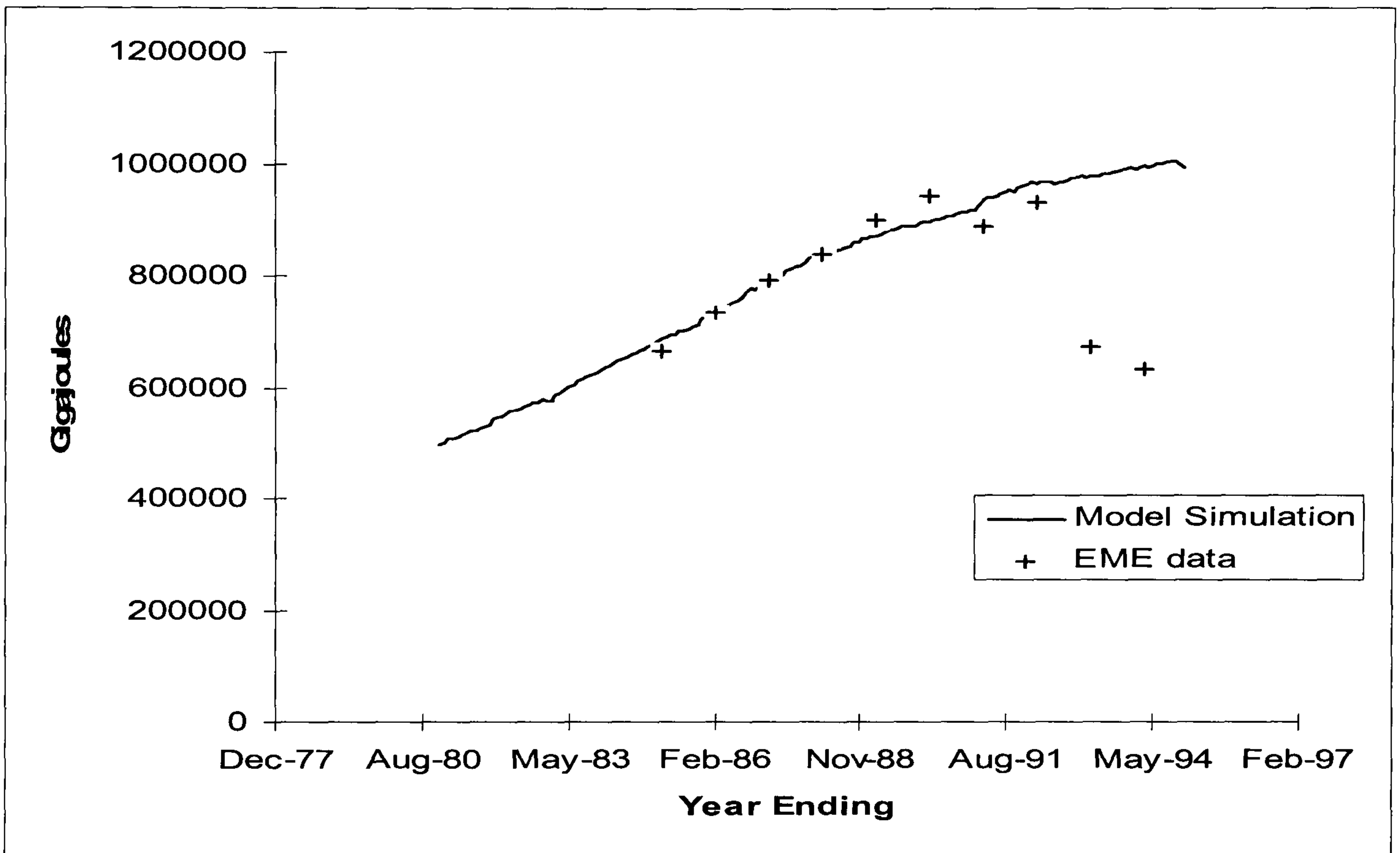

Figure 3.5: A Comparison of the Model Simulation of Industrial Sector Annual Rolling Electricity Demand and Data on Actual Demand Supplied by East Midlands Electricity for the Same Period.

The errors in the model estimates of annual delivered electricity demand in this sector were between ±6%, excluding two points (Figure 3.5) where much larger errors were evident. It is thought that the large discrepancies in 1993 and 1994 are due to companies switching to alternative electricity suppliers when this option became available to them, or producing more of their own electricity using CHP.

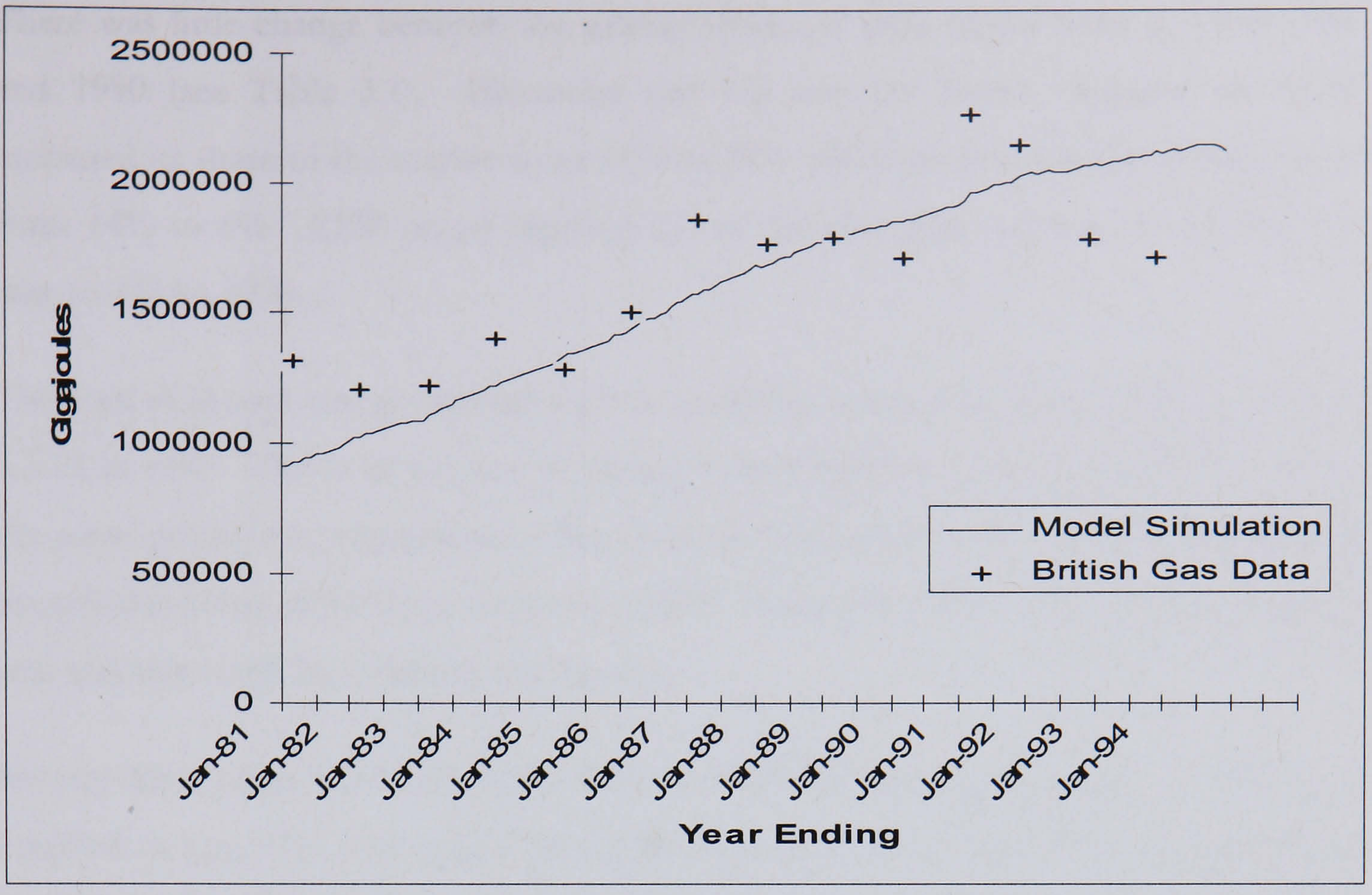

Figure 3.6: A Comparison of the Model Simulation of Industrial Sector Annual Rolling Gas Demand and Data on Actual Demand Supplied by British Gas Southern for the Same Period.

3.4.2.4 Overall Model Results

The model estimates that the annual delivered energy demand for residential, services and industrial sectors of the Council Area of Milton Keynes rose from 7.1 PJ in 1980 to 9.9 PJ in 1990, an increase of 38%. Energy demand for the transport sector was estimated to be 6.5 PJ in 1990 (Titheridge & Boyle, 1996b). The percentage split between the four sectors is as follows: domestic sector, 25%, services sector, 15%, industrial sector, 21% and transport, 40%.

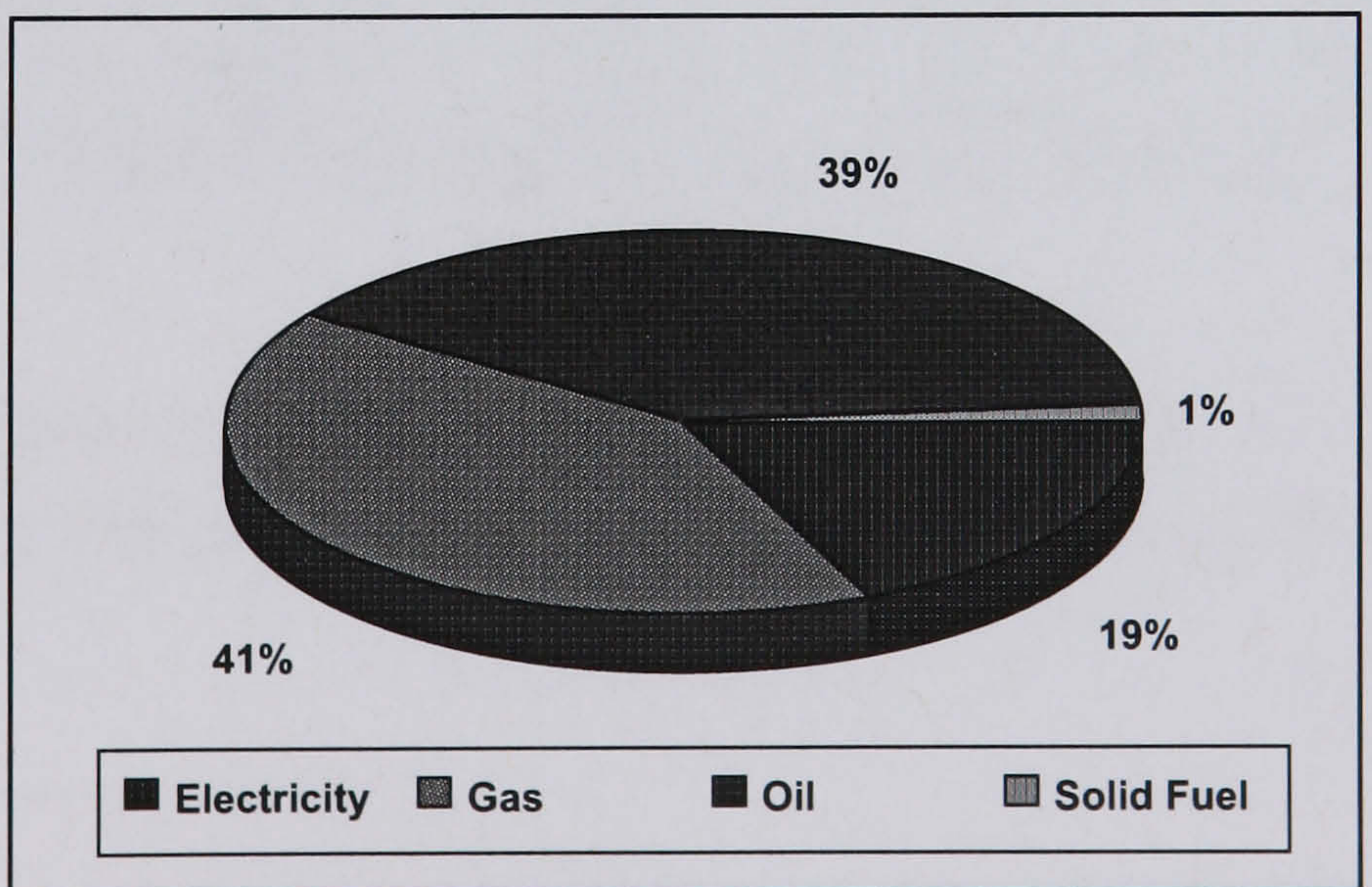

Figure 3.7: Total Delivered Energy Demand for 1990 by Fuel Type

There was little change between the market shares of each of the fuels between 1980 and 1990 (see Table 3.1). Electricity and Oil saw the largest changes: electricity increased its share of the market from 21% to 29% whilst oil decreased its market share from 14% to 6%. CHP plants supplied 1% of the electricity consumed in 1980; this rose to 3% by 1990.

The total delivered energy demand for the domestic sector rose from 3.2 PJ in 1980 to 4.3 PJ in 1990. This is an increase in energy consumption of 52% over 10 years. Over the same period the population of the Council Area rose by 40% and the number of households living in the Council Area by 53%[4]. However, 1990 was a particularly warm year and this could be distorting the figures.

Seventy-four percent of the total delivered domestic energy demand in 1980 was supplied by gas, 17% was supplied by electricity and an estimated 6% by oil and 3% by solid fuel. By 1990 22% of the total energy demand was supplied by electricity. This increase in electricity's share of the demand may be due a combination of three factors: an increase in appliance ownership; a decrease in heating demand as a result of better levels of insulation; or the warm weather of 1990. In 1980, space-heating accounted for 61% of the total domestic energy demand but only accounted for 51% in 1990, whilst hot water energy demand rose from 22% to 27% of the total demand over the same period. The energy demand for cooking, lighting and appliances also rose.

					PJ
	Electricity	**Gas**	**Oil**	**Solid Fuel**	**Total**
1980	1.71	4.90	1.13	0.23	7.96
	21%	*62%*	*14%*	*3%*	*100%*
1990	3.43	7.61	7.16	0.25	12.00
	29%	*63%*	*60%*	*2%*	*100%*

Table 3.1: Total Delivered Energy Demand by Fuel Type

The total annual delivered energy demand in the industrial sector rose by just over 40% between 1980 and 1990, from 2.45 PJ in 1980 to 3.45 PJ. During the same time period

[4] Source: Milton Keynes Development Corporation and Commission for New Towns, Facts on Milton Keynes, March 1980 - Dec. 1993

industrial floor area[5] and manufacturing output[6] tripled. The largest increase in output was from the Electrical and Electronic Engineering sub-sector (Standard Industrial Classification, Class 34), which was one of the least energy intensive sub-sectors, requiring on average only 4.5 MJ/£ of production in 1984. In 1980 34% of the total annual delivered energy demand was met by gas, 19% by electricity, an estimated 43% by oil and 4% by solid fuel. By 1990 26% of the demand was met by electricity, 51% by gas, only 19% of demand was met with oil, and as for 1980 4% was met by solid fuel. It was estimated that 11% of the electricity used by the industrial sector in 1990 was produced locally by CHP plants, a dramatic increase on the estimated 1% produced locally in 1980.

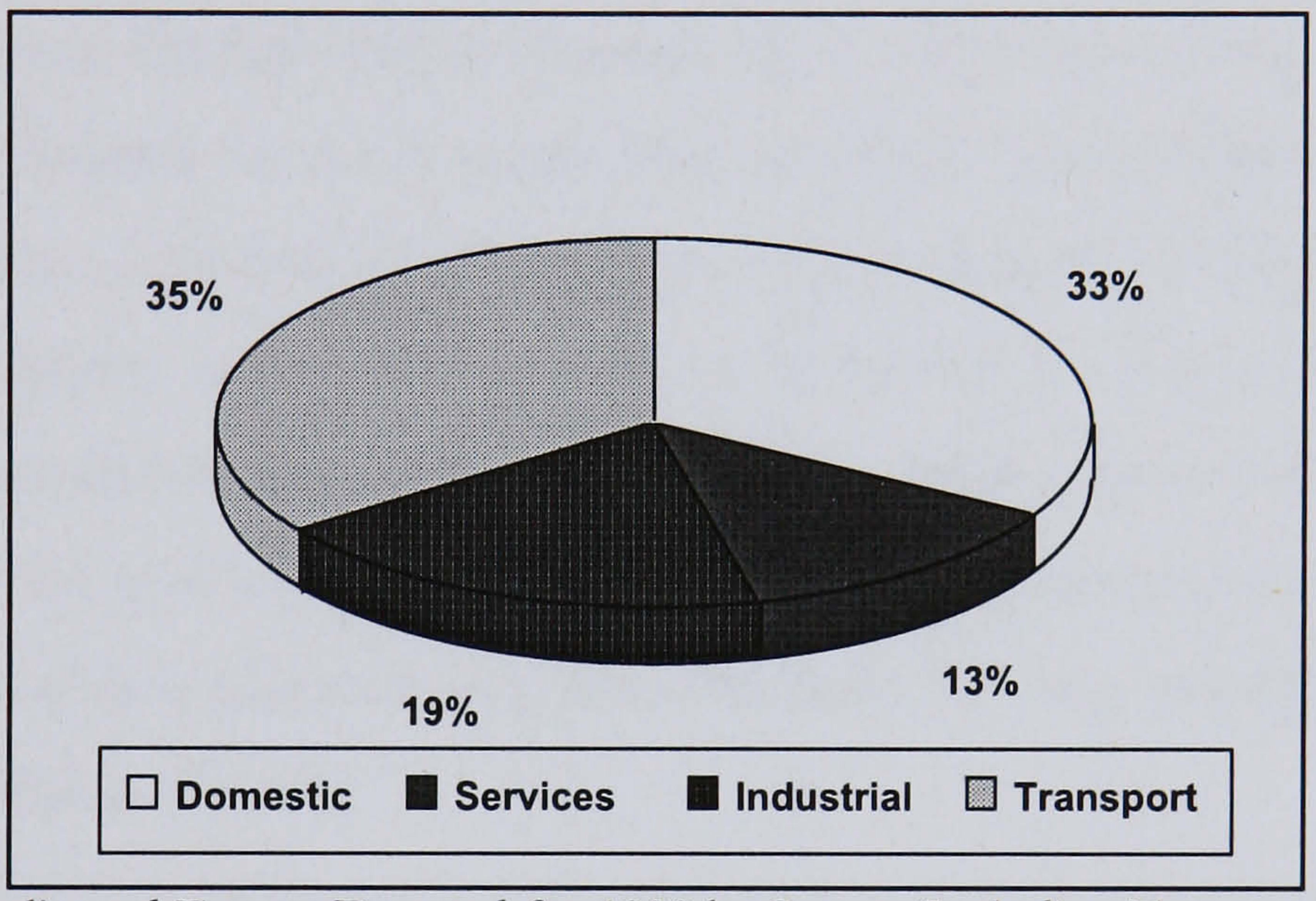

Figure 3.8: Total Delivered Energy Demand for 1990 by Sector (Including Transport Energy Demand)

Total annual delivered energy demand for the services sector rose from 1.46 PJ in 1980 to 2.38 PJ in 1990, an increase of 63%. During the same period, commercial floorspace[7.] rose from just under 200,000 m^2 to over 700,000 m^2. In 1980 24% of demand was met by electricity, 68% by gas, 3% by oil and 4% by solid fuel. By 1990

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[5] Source: Milton Keynes Development Corporation and Commission for New Towns, Facts on Milton Keynes, March 1980 - Dec. 1993. These figures possibly include warehousing floorspace, which has been included in the services sector sub-model rather than the industrial sector sub-model.

[6] Source: Central Statistics Office, Local Authority Analysis for Milton Keynes, 1981 and 1992

[7] Source: Milton Keynes Development Corporation and Commission for New Towns, Facts on Milton Keynes, March 1980 - Dec. 1993. These figures do not include warehousing and public buildings, which have been included in the services sector sub-model.

26% of demand was met by electricity, 68% by gas, 2% by oil and 3% by solid fuel. The amount of electricity supplied to the services sector increased by 75%, reflecting the increased use of electrical appliances and increased use of air conditioning. CHP provided less than 2% of electricity demand in 1990.

Insufficient data was available to produce a meaningful estimate of energy demand due to private sector travel for years earlier than 1990. Therefore, only the energy demand for 1990 will be described here. The majority of the transport energy demand was supplied by petroleum products; it was estimated that less than 1% of the total energy demand for this sector was met by electricity. However, this figure may be slightly underestimated as national figures on electricity use for rail transport were used. The West Coast main line through Milton Keynes, upon which one assumes the majority of rail journeys by residents of the Council Area are made, has undergone electrification. The transport sector total energy demand was estimated to be 6.5 PJ (Table 3.2). The overwhelming majority of the energy used in 1990 was for car travel (63%). Road vehicles (passenger and freight) used 92% of the transport sector total energy. Freight travel accounted for just over 30% of the total energy consumption. However, this figure probably does not take into account adequately the large numbers of distribution depots based in Milton Keynes.

In 1990 the total energy demand for the Council Area including energy used for transport was 18.5 PJ. The split between the main fuel types was electricity 34%, Gas 41%, Oil 19% and Solid fuel 1% (Figure 3.7). The split between the four sectors was as follows: domestic sector - 33%, services sector - 13%, industrial sector 19%, transport sector - 35% (Figure 3.8).

	Energy Demand	
	PJ	*(%)*
Road	5.95	(92.07)
Cars	4.31	(66.77)
Bus/Coach	0.1	(1.58)
Goods Vehicles	1.53	(23.72)
Rail	0.11	(1.69)
Water	0.4	(6.24)
Total	6.46	(100)

Table 3.2: Total Delivered Energy Demand for the Transport Sector

3.5 A Comparison with Other UK Towns

The energy consumed per capita in Milton Keynes has been compared with consumption levels for a number of UK cities and with the UK as a whole. The biggest difficulty when comparing energy consumption data for different cities is the way in which the energy consumption due to transport has been calculated. The DREAM model calculates the energy consumption due to travel based on the entire length of trips made by the residents and businesses of the city (air travel is excluded). Other studies such as the Newcastle study (Newcastle upon Tyne City Council, 1992) and the London Energy Study (Chell and Hutchinson, 1993) are based on total travel within the city boundaries.

Energy consumption per capita for Milton Keynes is similar to that for the UK, and compares favourably with Leicester, the only city listed in Table 3.3 where transport energy consumption was measured on the same basis as Milton Keynes data. Milton Keynes domestic energy consumption is low compared with the UK and with the other cities listed. It is thought that this is the result of the relative newness of the majority of the housing stock, the CNT's policy on energy efficiency and higher than average household sizes – 2.61 persons in 1991 compared with the national average of 2.49 (OPCS, 1993). The relatively young population of the city – 78.5% were under 50 in 1993 compared with 68.75% nationally (MKDC, 1993) – is also a possible contributing factor.

Energy Consumption	Milton Keynes[1] GJ/capita	London[2] GJ/capita	Leicester[1] GJ/capita	Newcastle[3] GJ/capita	UK[4] GJ/capita
Domestic	26.8	32.1	38.6	30.6	29.7
Services	15.7	21.4	18.8	12.0	13.1
Industry	22.2	9.8	53.3	15.5	29.6
Sub Total	64.7	63.3	110.6	58.1	72.4
Transport	42.5	25.8	22.8	17.1	35.1
Grand Total	**107.2**	**89.1**	**133.4**	**75.2**	**107.5**
Population	*153,000*	*6,680,000*	*272,000*	*280,000*	*57,808,000*

Notes:

[1]Data for 1990 derived using the DREAM-City model.

[2]Data for 1991 based on figures from Chell and Hutchinson (1993).

[3]Data for 1990 based on figures from Newcastle upon Tyne (1992).

[4]Data for 1990 based on figures from Herring (1994).

Table 3.3: Energy Consumption per capita for a selection of cities and for the UK.

Milton Keynes has a higher level of energy consumption per capita in the services sector than for the UK but a lower level of energy consumption per capita in the industrial sector. The differences between the cities can be largely explained by a combination of the ratio of homes to jobs within each city and the types of firms located within the city. For example, Leicester has strong footwear, clothing and hosiery manufacturing industries which are relatively energy intensive whilst London and Milton Keynes are much more service industry based.

Finally, the transport energy consumption per capita for Milton Keynes is considerably higher than that for the other UK cities or for the UK as a whole. As already mentioned there are differences in the methodologies used by the different studies for calculating transport energy consumption and this may account for some of the differences. However, Leicester transport energy consumption was calculated on the same basis as Milton Keynes and a marked difference in consumption per capita levels is still evident. A second and more probable reason for the differences is the size of the settlements in terms of population. Leicester and Newcastle are almost twice the size of Milton Keynes. Past research (e.g. ECOTEC 1993) has shown that both average journey lengths and modal split, and thus energy consumption, will vary with settlement size.

The evidence seems to suggest that Milton Keynes is energy efficient in some respects such as the standards of insulation for new domestic buildings but is less energy efficient in others – particularly personal travel. However, journey lengths are likely to increase as Milton Keynes matures, increasing energy consumption levels. Transport energy use already accounts for over 40% of the city's consumption. Additionally, as Milton Keynes matures the average age of its building stock will age whilst the oldest stock in other cities will undergo renewal or refurbishment. Thus, the gap between the average energy efficiency rating for Milton Keynes building stock and the building stock of other cities will close, leaving Milton Keynes with all of the disadvantages of its transport system and none of the advantages of an extra efficient building stock. A comprehensive and integrated energy strategy is required if Milton Keynes is to continue to meet its goal of being a resource efficient town. The uniqueness of Milton Keynes also would suggest that an "off-the-shelf" policy package is unlikely to fulfil this requirement.

ENERGY REDUCTION AND EMISSIONS MITIGATION OPTIONS

The Potential for Change in Milton Keynes

4.1 INTRODUCTION

This chapter discusses the variety of options available to Milton Keynes for reducing the environmental impacts of its energy consumption. The options discussed include fuel switching, the use renewable sources, improved efficiency of energy management and use, and behavioural changes. Mitigation options are discussed in the following sections grouped by the sector to which they are most appropriate – power generation, industry, buildings and transport. The potential of each technology within the borough of Milton Keynes is discussed with reference to its costs and benefits.

4.2 POWER GENERATION

There are three main ways in which the environmental impact of electricity generation can be reduced: - (1) through efficiency improvements, using the latest most efficient technologies when installing new generating plant; (2) through use of clean burn technologies, including flue gas scrubbing, which reduce the level of air-borne pollutants emitted; and (3) by switching to cleaner, less polluting fuels.

Milton Keynes will have little influence over the efficiency of existing large-scale electricity generating plant supplying National Grid base load, particularly, as there are no such plants within the borough boundaries. These types of generation plant are thus not discussed here. The type of influence that can be exerted includes buying electricity direct from the more efficient and "green" suppliers. There is, however, considerable potential for small and medium-scale electricity generation within the city. Some of the schemes discussed in this section may require consortiums or partnerships to create enough demand to be economic.

4.2.1 Co-Generation

Combined heat and power (CHP) can yield overall energy conversion efficiencies of between 80 and 90% depending on the utilisation rate of the heat and electricity produced (PIU, 2002, p191). Electrical efficiency is typically around 45%. CHP can use a variety of fuel types including biomass and varies in size from plant rated at a few kW_e

to 1000 MW_e. The market for medium to large-scale CHP (typically 30 kW_e to 30 MW_e is well established (*ibid*). Smaller-scale mini-CHP (suitable for smaller commercial sites) has recently become commercially available and micro-CHP (suitable for domestic use) is undergoing commercial trial (*ibid*). Electrical efficiency of micro-CHP is currently around 10-15%. The PIU (*op. cit.*) estimate that by 2050 micro-CHP could cost only £200-300 more than a conventional gas boiler.

The potential for CHP depends very much on industrial heat loads and the development of district heating/cooling networks. In the UK (among other countries) deregulation of the electricity market has made it easier for industrial users to generate their own electricity. The possibilities of co-generation in Milton Keynes are dependent on the amount of heat that can be utilised. Space and Water heating demand across all sectors in 2000 was 11.2 PJ, with additional heat demand from industrial processes, based on the DREAM-MK model results. The annual baseload demand for space and water heating is 4.3 PJ. Typically, CHP produces between 2 and 3 units of heat for every 1 unit of electricity produced. Thus theoretically, there is the capacity for all of the electricity demand in Milton Keynes to be met through CHP. However, greater rates of return on investment are obtained if the CHP systems are designed to meet the baseload heat demand. In this case, over a third of electricity demand can be met through CHP based on DREAM-MK model results. The market potential is likely to be much lower, due to problems such as matching heating load to electrical load, and plumbing existing buildings into combined heat and power systems.

4.2.2 Fuel Cells

Fuel cells use an electrochemical process to convert hydrogen (with oxygen from the air) into electricity. Fuels such as methanol, natural gas and coal can be converted to hydrogen through either an inbuilt or separate reformer. There several types of fuel cell currently available. The types include: proton exchange membrane cells, phosphoric acid cells alkaline cells, direct methanol cells, molten carbonate cells and solid oxide cells. The efficiencies, fuel use, market and costs of each type differ (see table 4.1). The Performance and Innovation Unit (PIU, 2002) estimates current costs of between US$2000/kW (£1600/kW) and US$10,000/kW (£7500/kW), reflecting the newness of the technology, consisting of prototypes or fuel cells aimed at a very small commercial market.

Although, most frequently discussed in terms of the transport market, fuel cell technology also has the potential for small-scale (less than 1MW) decentralised stationary power generation. Indeed the PIU (2002) estimate that this market is likely to be developed before the transport market. The waste heat produced by the fuel cells can be used for cogeneration, although the applications will be limited by the type of fuel cell and its operating temperature (see table 4.1).

Proton exchange membrane fuel cells (PEMFC) currently have conversion efficiencies of around 45% using hydrogen (Laughton, 2002). This is expected to rise to between 55% and 60% in the near future (IPCC, 2001). Phosphoric acid fuel cell (PAFCs) applications include an 11 MW plant in Goi, Japan. Natural gas to electricity conversion efficiency is around 40%-45% for PAFCs, reaching much higher levels if used for cogeneration (Laughton, 2002). Estimates of current costs range from US\$1500/kW$_e$ (IPCC, 2001) to between \$2000 and \$10000/kW (PIU, 2002). These costs are expected to halve by 2010, with efficiencies rising to 50% and over 90% if used for cogeneration (IPCC, 2001).

Characteristics	Operating temperature	Co-generation heat	Electrical efficiency,%
AFC	60 –90	Low temperature	60
PEMFC	70 –100	Low temperature	40 –45
DMFC	90	Low temperature	30 –35
PAFC	150 –220	Temperature acceptable for many applications	40 –45
MCFC	600 –700	High temperature	50 –60
SOFC	650 –1000	High temperature	50 –60

Notes: AFC is Alkaline Fuel Cell. PEMFC is Proton Exchange Membrane Fuel Cell. DMFC is Direct Methanol Fuel Cell. PAFC is Phosphoric Acid Fuel Cell. MCFC is Molten Carbonate Fuel Cell.SOFC is Solid Oxide Fuel Cell. Reformate is pure hydrogen, or a hydrogen-rich gas, produced by reforming fossil fuels
Source: based on Laughton,2002

Table 4.1: Properties of different fuel cell types

The potential for fuel cell technology to substantially cut carbon emissions and reduce consumption of non-renewable resources, particularly in the transport sector, is dependent on the method used to produce the hydrogen used by the fuel cells. On-vehicle reformation of petroleum absorbs considerable energy (PIU, 2002) which would negate any efficiency gains from using fuel cells instead of internal combustion engines.

4.2.3 Fuel Switching and Alternative Sources

Another method for reducing the environmental impacts of energy consumption is to use less-polluting energy sources, i.e. to switch from coal and oil to gas or renewables. This has already been happening extensively within the UK electricity generating industry. Two-fifths of the reduction in carbon dioxide emissions achieved in 2000, compared with a 1990 baseline, was due to the switching from coal to combined cycle gas turbines for electricity generation (Dti, 2002). Switching to gas and nuclear power plants to replace coal-fuelled plants reduced overall carbon dioxide emissions from power plants by 20%.

Obviously, switching to gas can only be viewed as an interim measure as gas still produces some emissions. Natural gas produces 14 kg of carbon dioxide per GJ whilst oil produces 19 kg per GJ and coal 24 kg per GJ. Natural gas is also a non-renewable resource.

4.2.3.1 Hydroelectricity

Currently, there is around 700 GW of installed hydroelectric capacity installed worldwide (WEC, 2001) providing 19% (2650 TWh per year) of the world's electricity supply, although there is some uncertainty due the difficulties of estimating the level of small-scale and private capacity. Current load factors are around 40%, depending on such factors as demand and variations in water supply. Turbine efficiencies of over 95% can currently be achieved (Ramage, 1997) and generating capacity ranges from micro-turbines with output of less than 1kW to large dams with outputs in excess of 1000MW. Average generating costs are around 0.065 US$/kWh (IPCC, 2001).

The total theoretical hydroelectric potential is estimated as being between 36,000 and 44,000 TWh per year (UNDP, 2000), although some estimates put the world theoretical potential higher: for example Ramage (1997) suggests the total resource is around 50,000 TWh per year. The amount of hydro which is technically exploitable is somewhat lower at around 14,400 TWh per year (WEC, 2001), with the economic potential capacity lower still at around 8000 TWh per year. Currently about 65% of the technical potential of Western Europe has been developed (World Atlas and Industry Guide, 1998). In the UK there are currently over 50 large hydro schemes and many more small-scale schemes – contributing to 1.5% of the nation's electricity requirements (PIU, 2002). However, there is little potential for electricity generation from hydro resources within Milton Keynes, as the watercourses flowing through the area do not have either sufficient flow rates or head.

4.2.3.2 Solar Photovoltaics

World solar energy potential is between 1,500 and 50,000 EJ/year, based on estimates of available land (IPCC, 2001). This is well over four times current global energy use even if the lower estimate is correct. However, the market potential for solar radiation capture is much lower due to a number of reasons, including its relatively high price at present, daily and seasonal fluctuations in the amount of radiation received, thus necessitating storage (if not connected to the grid), and the diffuse nature of the radiation reaching the surface, particularly in the lower latitudes with low power resulting in large equipment and land requirements.

Installed capacity worldwide is 600-800MW (WEC, 2001). However, the uptake rate in the UK has been slow compared with sunnier climates due to low radiation levels. Installed capacity in the UK was 670kW in 1998 (RCEP, 2000) mainly used to power remote telecommunications, satellites and signalling equipment. This is a fraction of the estimated maximum practicable resource of 30 GW, based on utilising all available building surfaces (PIU, 2002). ETSU estimate that the total cost-effective resource[8] will be less than 0.1 GW by 2025 (*ibid*).

Milton Keynes Energy Agency (MKEA) (2001) estimates that the average daily solar radiation received in Milton Keynes on a horizontal surface is 2.6 $kWhm^{-2}$. This gives a potential resource for the borough of 90 GWh based on an assumption that a quarter of properties within the borough are unsuitable due to factors such as poor orientation and overshadowing.

Markets for PV power generation systems include off-grid applications for rural areas, grid-connected urban buildings (as part of an integrated system), and grid-connected power stations. Annual world sales of PV systems were 130MW in 1997, and the market is anticipated to grow to 1000MW by 2005 (Varadi, 1998). The costs of photovoltaics have been falling and are expected to continue to do so. Current costs of

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[8]ETSU's estimate of the rate at which electricity could be generated at a cost of less than 7p/kWh in 2025, assuming an 8% discount rate

PV electricity are around 70p/kWh (PIU, 2002). These costs are likely to fall in the UK to between 10 and 16p/kWh over the next 20 years (*ibid*).

Conversion efficiencies are low but improving. Efficiencies of 24.4% and 19.8% have been obtained in the laboratory for silicon monocrystalline and multicrystalline cells respectively (IPCC, 2001). Commercial monocrystalline modules are obtaining efficiencies of between 13% and 17% and multicrystalline between 12% and 14% (*op. cit.*). Thin film technologies are less efficient still (6%-8%) but cheaper to produce. Recycling of PV modules is also being developed and is currently at the pilot stage (Fthenakis *et al*, 1999).

Within Milton Keynes, the high cost of solar photovoltaic systems means that they are unlikely to make a significant contribution in the short to medium terms, although there is potential for demonstration projects, "high profile prestige projects" and specialist applications. High profile prestige projects include proposals for an integrated PV system on the National Energy Centre; whilst specialist applications include off-grid applications such as street furniture, parking meters (already in use) and security lighting.

4.2.3.3. Biomass Conversion

Hall and Rao (1999) estimate that global primary production of biomass is 220 billion oven-dry tonnes (odt) per year; this equates to 4500 $EJyr^{-1}$. Less than 10% of this could sustainably become available for bioenergy – 270 EJ each year (Hall and Rosillo-Calle, 1998) depending on the economics of production and land availability. In addition to energy crops, biomass resources include agricultural and forestry waste, municipal waste, and landfill gas. Current world consumption of biofuels is just over 55 EJ (op.cit.), although a large proportion (45-50 EJ) of this is used for domestic cooking in developing countries, in often-inefficient woodstoves (Hall, 1991).

The wide distribution of biomass makes it a good potential energy source for rural populations. Incineration of municipal waste is suited to urban areas. Transport methods and distances have significant impact on the energy balance of the overall biomass system (IPCC, 2001). The generating plant or biorefinery must be located in such a way as to minimize transport costs. Biofuels such as woodfuel and energy crops are often cited as being carbon-neutral i.e. that the carbon dioxide produced during the combustion process equals that taken up by the plants as they grow. However, the energy consumed in harvesting, processing and transporting the biomass to the generating plant can be considerable, with all the environmental consequences associated with such energy-use. Mann and Spath (1997) showed, using life cycle analysis, that for electricity produced using biomass-fuelled Integrated Gasification Combined Cycle plant (BIGCC) that 95% of carbon delivered was recycled, or for every 1 unit of fossil fuel used, 16 units of carbon-neutral electricity were generated. The Royal Commission on Environment and Pollution (RCEP, 2002) suggest that installed capacity at individual sites should be kept low (30MW) with the biomass being transported no more than 40 km to the site. However, Dornburg and Faaij, (2000) suggest that savings from economies of scale are more significant than the additional transport costs involved to achieve these economies.

There is usually a cost involved in the disposal of agricultural and forestry wastes. Therefore, using these wastes to provide heat and power, particularly for local rural community applications, often has good economic and market potential (IPCC, 2001). In the sugar cane industry, bagasse residues are commonly used for on-site co-generation; excess power is exported (*op. cit.*). The current cost of generating electricity by burning agricultural and forestry wastes is 3.5 to 4.0 p/kWh (UNDP, 2000).

The cost of producing electricity from energy crops depends on a number of factors including the amount of competition for land from the food and fibre production industries, and the technology used. Biomass-fuelled integrated gasification combined cycle (BIGCC) plant operating costs (including fuel) are predicted to fall from the current cost 0.04 US$/kWh to 0.03 US$/kWh by 2030 (EPRI/DOE, 1997). Operating costs of conventional boiler/steam turbine technology burning biomass are currently 0.055 US$/kWh, due to lower fuel efficiencies. The cost of generating electricity from energy crops in the UK is expected to be between 2.5 and 4.0 p/kWh by 2020. The current cost of generating electricity from energy crops in the UK is around 8 p/kWh (PIU, 2002).

Milton Keynes has woodland/park residue biomass available from a variety of sources including Milton Keynes Council, the Milton Keynes Parks Trust and Marston Vale community forest. A report produced for the Milton Keynes Parks Trust in 1999 (Bright, 1999 cited in MKEA, 2001) recommended that the Trust commit to supplying 750 tonnes of biomass per annum for energy use (equating to 1.9GWh of thermal energy); this was based on an assessment of the potential of the 640 hectares managed by the Trust to produce biomass for energy. Milton Keynes does not have a significant agricultural waste resource (MKEA, 2001).

Milton Keynes currently produces over 80,000 tonnes of municipal solid waste per year, much of which is send to landfill (ETSU *et al*, 2000). The Council currently sends waste to three different sites, only one of which is within the council boundary. Landfill gas produced at these sites is being used to generate electricity. Installed capacity across the three sites is over 20MW. As additional areas of the sites are filled and capped, more opportunities to generate electricity will become available. The Newton Longville site is expected to remain open for another 15 to 20 years. Methane is produced at maximum concentration for up to 15 years after the waste was deposited; although not at maximum, concentrations may still be sufficient for electricity generation for a further 5 years.

Municipal solid waste could alternatively be incinerated to produce electricity. However, the Government's Waste Strategy 2000 for England and Wales (DETR, 2000) encourages waste minimisation followed by maximum value waste recovery from the residual waste. Maximum value waste recovery suggests use of the following methods in this order – recycling, composting, other forms of material recovery such as anaerobic digestion, then energy recovery. Thus it can be expected that the resource of municipal waste incineration for electricity generation will decrease in the future.

4.2.3.4 Wind

Wind in 2000 supplied around 0.1% of total global electricity, but accounted for 0.3% of installed generation capacity (IPCC, 2001). This is because of the intermittent nature of wind and the relatively recent emergence of the technology. Over 40,000MW of capacity was installed worldwide at the end of 2003 (BTM Consult, 2004). Installed capacity has doubled every two and a half years (Boyle, 2003). The cost of wind turbines has dropped dramatically over this period and continues to fall (IPCC, 2001). In areas with high wind speeds, wind power is competitive with other forms of electricity generation. In the UK, average tendered prices for wind-generated electricity under the NFFO agreement were 2.85 p/kWh in 1999 (Dti, 2001). Global average price for electricity generated by onshore wind turbines is expected to reach 1.5 to 2.5 p/kWh by around 2020 as a result of economies of scale of production as uptake of the technology increases, and improvements in turbine designs (UNDP, 2000).

Based on data from The World Energy Council (1994), UNDP (2000) estimated global theoretical wind potential to be in the region of 480,000 TWh per year, assuming 27% of the earth's land surface is exposed to mean annual wind speeds of over 5.1m/s at 10m above the ground. However, assuming that for practical reasons just 4% of high wind speed land could be used be used for wind power, then the World Energy Council's estimate is reduced to around 20,000 TWh/yr (WEC, 1994). The Global Wind Energy Initiative has demonstrated that an installed capacity of over 800GW by 2010 (including offshore installations) would be feasible (BTM Consult, 1998), whilst Greenpeace (1999) has estimated that by 2020 1,200GW could be installed, providing 3,000 TWh per year of electricity.

Wind speeds in Milton Keynes vary, with most sites having annual mean wind speeds of around $6ms^{-1}$ at 45m above ground level. Speeds in a few areas such as Brickhills are as high as $7ms^{-1}$. Currently in the UK, for wind power to be financially viable mean wind speeds of over $7ms^{-1}$ are normally required. MKEA (2001) have identified two sites suitable for small clusters of wind turbines (3-5) – Brickhills and an area of open countryside to the North of the Borough near the M1 motorway. In addition, MKEA identified over 20 employment sites, at least 400m away from existing or proposed residential development, which are suitable for one or more turbines.

IPCC (2001) estimate that in a large integrated electricity system, up to 20% of generating capacity could be provided by wind, without incurring significant penalty from the intermittent nature of wind power.

4.2.3.5 Geothermal

Geothermal electricity generating installed capacity (in 20 countries) was 7873 MW_e in 1998 (Barbier, 1999). Geothermal direct heat use was an additional 8700 MW_{th}. Nakicenovic *et al* (1998) estimate that this energy resource could be increased by a factor of 10 in the near term. However, there is little potential for tapping into this source within Milton Keynes, except through ground source heat pumps.

4.3 INDUSTRY

Significant energy savings have been made in the UK industrial sector. UK Industrial sector output rose by 13% between 1990 and 2000; energy consumption within the sector fell by 11% over the same period (Dti, 2001). This has resulted in an energy intensity reduction of 20% between 1990 and 1999. The vast majority of this reduction was due to improvements in efficiency (18%). The remaining 2% was due to structural changes (Dti, 2001). Energy savings in the Milton Keynes industrial sector are likely to be lower than those for the UK. The largest energy savings in the UK were made in the iron and steel and non-ferrous metals sectors, which reduced energy intensities by 31% between 1990 and 2000 (Dti, 2001). Milton Keynes has very little of this type of industry. Output from MK-DREAM suggests savings in the region of 4% were achieved over the past decade in the borough.

Industrial energy consumption can be divided into high temperature processes, low temperature processes, motors and compressors, specialist processes, space heating requirements and other supporting services such as communications and information technology and lighting. The proportion of energy used for each varies considerably, both between and within the different industrial sub-sectors, and thus the potential for saving energy varies considerably between industries.

Experience from the ETSU Best Practice and Good Practice Programmes illustrates the types of measures than can be implemented and the savings that could be achieved from these. For example, instigating monitoring and targeting practices have been shown to save between 2% and 14% of energy, paying back the money it cost to set up the scheme in under a year. Energy awareness training programmes have also performed well, paying back many times the training costs in the first year. Use of heat recovery can save a factory up to 20% of its energy demand with paybacks of 3.5 years and under. Fitting variable or twin speed fans can save 21%. The database in Titheridge (2004) provides a summary of the ETSU Good and Best Practice Programme results.

The Royal Commission on Environment and Pollution (2000) suggests that there are three broad approaches to improving manufacturing industry energy efficiencies. The first approach is to improve the efficiency of existing plant and processes through good housekeeping (management). This involves monitoring of buildings and equipment to make certain they are functioning effectively, ensuring buildings are not over heated and over lit, keeping plant well maintained and operating at optimum speeds. Additional energy meters and controls may need to be installed for this approach to be effective, and involvement of staff will be crucial. The second approach is to modify or retrofit existing plant. This could involve replacing individual components such as boilers with more efficient ones; or, installing insulation on pipe work. The final approach is to replace existing plant entirely. Where substantial energy savings (or other benefits such as increased productivity) can be achieved, there may be a case for replacing existing plant before the end of its operational life. The latter two approaches will be more effective in the long run if combined with better energy management.

ETSU suggest that energy savings of 8% could be achieved over the next 25 years in this sector, against a background of continued growth in output, if the third approach were adopted with all plant and equipment being replaced with high efficiency alternatives (cited in RCEP, 2000). The Policy and Innovation Unit of the Cabinet Office (PIU, 2002) is more optimistic, suggesting that the technical potential of energy efficiency savings is 35% and the economic potential is over 20% over and above the efficiency gains being made under "business as usual" conditions by 2010, based on Fisher *et al* (1998). However, these figures include the contribution made by CHP to the efficiency gains.

Different levels of savings can be achieved in different industrial sectors, depending on the types of processes involved. Table 4.2 shows the energy efficiency potential by industrial sector for the UK. The potential savings for Milton Keynes will be slightly different, reflecting the types of industry present within the Council Area.

Sector	**Energy Efficiency Potential to 2010 (Mtoe)**	
	Economic	**Technical**
Metals	2.2	3.2
Minerals and Ceramics	1.3	1.8
Chemicals	1.1	1.9
Food and Drink	0.7	0.8
Paper and Textiles	1.4	2.4
Engineering and Other	1.9	3.3
Total	**8.6**	**13.2**
Percentage of Demand	*24%*	*36%*

Source: PIU (2002)

Table 4.2: Potential Energy Efficiency Savings for the UK Industrial Sector to 2010.

4.4 Domestic Sector

Approximately two-thirds of building sector energy demand can be attributed to residential buildings and one-third to commercial buildings (IPCC, 2001). Energy consumption in residential buildings is strongly related to household incomes. Energy consumption in the UK domestic sector rose by 19% between 1990 and 2000, whilst the number of households rose by just 10% over the same period. From the results of the DREAM model, Milton Keynes energy consumption rose by 60% over the same period. Although, growth in energy demand in the UK from this sector has slowed over recent years (Dti, 2002), there is still a large potential for energy efficiency savings, as many technologies have not been adopted universally. PIU (2002) suggests that the current economic potential for savings in this sector for the UK is 17.4 Mtoe per year, i.e. 37.2% of current demand, giving a saving of £5000 million.

Space-heating is the most important energy end-use in the residential sector, with over 59 percent of domestic sector energy demand being used for this purpose in Milton Keynes in 2000, followed by water heating. Rises in the demand for space heating have occurred due to increases in the temperatures to which our homes are heated and a growth in the number of homes with central heating (which in turn affects mean internal temperatures) (Dti, 2002). DEFRA (2001) in their proposals for an "energy efficiency commitment 2002-2005" assume that households in receipt of income benefits will take 45% of the benefits of energy saving measures in increased comfort, whilst other households will take 15%. Table 4.3 shows mean internal temperature of domestic buildings in Great Britain for 1970 and 2000 compared to the mean external temperature for the same years.

	1970	2000
Mean External Temperature	5.8C	7.2C
Mean Internal Temperature	13C	18C

Source: Dti, 2002.

Table 4.3 UK Mean Internal and External Temperatures, 1970 and 2000.

Reductions in the amount of energy required to heat a home to a given level of comfort can be achieved through a number of means, including draught proofing, loft insulation, wall insulation, under floor insulation, double glazing, and increased boiler efficiencies. A number of studies have estimated the potential in the UK for savings from these technologies, e.g. Energy Savings Trust (1997, 1999, 2001), NES (1999) and BRE (cited in PIU, 2002). Table 4.4 summarises some of these.

Measure	Technical Potential (Mtoe)		Economic Potential to 2010 (Mtoe)		Overall Technical Potential (PIU)	
	BRE	NES	ACE	EST	Mtoe	MtC
Loft Insulation	1.71		1.06	0.06	1.7	1.38
Cavity Wall Insulation	3.17		3.03	2.3	3.2	2.59
Solid Wall Insulation	3.35	2.27	3.56		3.4	2.75
Double Glazing (+low E)	2.13		0.72	1.3	2.1	1.70
High Performance Glazing (U–value 0.9 or less)		1.5			1.5	1.21
Draught Proofing	0.41		1.15		0.4	0.32
H/W cylinder insulation	0.29		0.1	0.5	0.4	0.32
Condensing Boilers	6.15		0.82	1.5	6.5	5.26
Controls				0.5	0.5	0.40
Solar water heating	2	2			2.0	1.62
Ground source Heat Pump		2.8			2.8	5.25
TOTAL					27.0	27.50

Source: PIU (2002)

Table 4.4: Potential Energy Efficiency Savings for the UK Domestic Sector to 2010.

The fastest growing end use for energy in the UK domestic sector is electricity for lighting and appliances. Two main factors are attributed to this trend: the rising affluence of households and the increasing number of households as household sizes decrease. A number of strides have been made towards reducing the energy consumption of appliances e.g. through energy labelling schemes. Dti (2002) estimates that since the introduction of energy labelling in 1990 on cold appliances there has been a 27% reduction in consumption of energy by these appliances. The DECADE project undertaken by Oxford University's Environmental Change Unit is the key source of information on the energy consumption of domestic appliances and lighting in the UK. DECADE (ECU, 1997) reports that energy consumption from domestic lighting and appliances doubled between 1975 and 1995. The report goes on to suggest potential savings of 33% (27 TWh) of 1990 levels could be achieved by 2010 from the adoption of efficient appliances. Sixty percent of these savings were from cold appliances and lighting. A further 8 TWh (12%) of savings could be achieved by residents making changes to their usage patterns (*ibid*). The biggest areas for savings from behavioural changes were in cooking, wet appliances (e.g. washing machines, dishwashers) and lighting. The DECADE report (*ibid*) identified further carbon savings that could be made by switching from gas to electric, i.e. through use of hot fill washing machines instead of cold fill, and the potential for time-shifting the use of wet appliances, in particular, away from times of peak demand to times of lower demand. Table 4.5 outlines the results of the DECADE investigation into the potential savings from domestic appliances.

					TWh (%)
Appliance Group	1996 Consumption	Reference Case (2010)	ETP2002 (2010)	Savings	
Cold	17.5	16.1	8.7	7.4	(46%)
Wet	12.0	12.4	10.4	2.0	(16%)
Cooking	12.8	14.3	10.5	3.8	(27%)
Lighting	17.2	20.2	10.7	9.5	(47%)
Brown	8.4	9.5	5.5	4.0	(42%)
Misc	6.1	7.8	7.8	0	(0%)
Total	74.1	80.4	53.6	26.8	(33%)

Source: ECU (1997)

Table 4.5: Potential Energy Efficiency Savings from UK Domestic Appliances to 2010.

4.5 Services Sector

Over the past decade the energy intensity of commercial buildings in the UK, in terms of annual energy consumption per unit of floor area, has been roughly constant, and may even have been increasing (RCEP, 2000). An increasing number of non-domestic buildings are being constructed with full or partial air conditioning. More than 25% of non-domestic floorspace constructed since 1991, has some air conditioning. There is no reason to believe that the trends in Milton Keynes are any different. The number of office appliances in use has also been growing rapidly.

RCEP (2000) found that the technical potential for reducing energy consumption within the services sector was 18% by 2010. Economically, with current low energy prices, a saving of only 3% could be achieved. The PIU (2002) are more optimistic, estimating that the current economic potential for energy savings in this sector is 21%. The UK Government in their white paper on climate change (DETR, 2000) suggest that 20% of carbon emissions from the commercial sector could be saved through "cost effective" measures, based on estimates provided by the Building Research Establishment. Carbon savings in the public sector (based on current trends) are likely to be in the region of 22% from a base line of 1990 (DETR, 2000). The latest Government plan for action with regard to energy efficiency (DEFRA, 2004) suggests a technical potential for carbon savings from the services sector of 16MtC, with cost-effective measures providing savings of 6MtC by 2010. The UK services sector was responsible for 19MtC in 2000 (PIU, 2002).

The range of options for achieving these savings include improved controls for lighting, heating and cooling equipment and use of energy efficient appliances. RCEP (2000) suggest that the greatest scope for energy savings within non-domestic buildings comes from new buildings, through integrated building design. Integrated building design brings together all the above energy saving opportunities – building shell, building siting, appliances, heating and air conditioning equipment and building controls – in such a way as to maximise the synergistic effects. Energy savings from integrated building design for residential buildings have been found to be between 30% and 60%, and between 13% and 71% for commercial buildings (IPCC, 2001). The potential of energy savings from integrated building design is severely limited by the rate of turnover of UK building stock. New building rates for the services sector are in the region of 1-2% per annum (DEFRA, 2004).

In this respect Milton Keynes has more opportunity than most municipalities, due to the substantial growth expected in the borough over the next 25 years. Milton Keynes Council already requires housing to be built to higher energy standards than required by the current building regulations and the outline energy strategy for Milton Keynes (MKEA, 2002) discusses the possibility of setting an energy efficiency standard for non-domestic buildings, similar to that already adopted for residential buildings.

As well as the opportunities described above for reducing energy consumption in buildings, Milton Keynes also has the option of using solar thermal systems for water heating in both domestic and non-domestic buildings. Solar water heating could provide at least half of the annual hot water requirements for a home. Better efficiencies can be achieved in the non-domestic sector, for either water heating or process pre-heating, where the demand is during the day and thus less storage is required. MKEA (2001) estimates that the theoretical resource for solar thermal is just under 80GWh for Milton Keynes. MKEA went on to identify a number of residential and employment areas with east-west road orientations, which they suggest are particularly suited to solar water heating.

4.6 Transportation

Vehicle fuel efficiency in the UK has been increasing in recent years (Dti, 2002). However, these efficiency gains have been offset by increased levels of travel and the switch from public transport to cars. In addition, some of the engine efficiency gains have been countered by an increased demand for more powerful engines, energy-consuming features such as power steering and air conditioning, and new safety features which have resulted in heavier vehicles. There are three main technological options for reducing the environmental impact of transport – vehicle efficiency improvements, exhaust gas cleaning and alternative fuels. There are also a number of non-technological or soft measures. PIU (2002) estimates that the current economic potential for savings in this sector is 19.3 Mtoe per year, giving a saving of 31% valued at £12,300 million.

4.6.1 Vehicle Efficiency

4.6.1.1 Direct Injection Gasoline and Diesel Engines

Direct Injection Gasoline engines have already been introduced in Japan and Europe. Elsewhere use of direct injection lean-burn gasoline engines has been restricted due to the high sulphur content of gasoline, for example in the USA. Many countries are in the process of setting limits on the sulphur content of gasoline, so this restriction could be lifted in the near future. Engine costs are moderate, between US$200 and US$300 more than a conventional engine (IPCC, 2001).

Direct Injection Diesel engines attain approximately 35% greater fuel economy than conventional gasoline vehicles and produce about 25% less carbon emissions over the fuel cycle (IPCC, 2001). The engines cost between US$500 and US$1000 more than conventional gasoline engines.

4.6.1.2 Gearbox Improvements

Operating vehicles at their maximum efficiency reduces fuel consumption and carbon dioxide emissions. A petrol engine will typically deliver only 24% of the heat energy of the fuel to the crankshaft. This figure rises to 32% for diesel (Everett, 2003). Best engine efficiencies are obtained at around 3000rpm for petrol engines and at around 2000rpm for diesel engines (*ibid*). The Gearbox is used to match the engine speed to the road speed. The more gears in a gearbox the easier it is to maintain engine efficiency at different cruising speeds. Six or even seven speed gearboxes are becoming increasingly widespread (Wells, 2001 cited in Fergusson, 2001). Automatic gearboxes, popular in Japan and the USA, and automated manual gearboxes, as in the SAAB sensonic, are also effective for governing engine speed (*op. cit.*), although automatic gearboxes tend to have higher energy losses than manual gearboxes.

4.6.1.3 Hybrid Electric Vehicles

Hybrid electric vehicles combine a fuelled power source such as an internal combustion engine (ICE) with an electric drivetrain and storage device (for example a battery or fuel cell). Fuel economies are gained through (1) the recapture of braking power with the electric motor used as a generator and resulting electricity being used to top up the battery; (2) downsizing of the engine enabled by using the motor and battery together to boost the power when required; (3) avoidance of idling losses by storing unused power in the battery; and (4) increasing engine efficiency by using the generating and storage capacity of the electric system (motor and battery) to keep the engine operation away from low efficiency modes. Several models are currently on the market (e.g. the Toyota Prius), and more are in advanced stages of development (IPCC, 2001). The fuel economy of the most efficient hybrid designs is as much as 50% greater than conventional vehicles under average driving conditions (IPCC, *op. cit.*; Fergusson, 2001), however, efficiency gains in the region of 20-30% are more likely (Fergusson, *op. cit.*). In slow stop-start driving conditions typical of heavily congested urban areas, efficiency gains could be greater still as ICEs are at their least efficient in these conditions. This makes hybrid vehicles ideally suited for the urban environment. Efficiency gains are minimal in long-distance, constant high-speed conditions. The complexity of the dual system adds significantly to the costs of producing a vehicle so uptake could be slow without intervention such as subsidized pricing. The Toyota Prius has a premium of £3000 (20%) over similar conventional models but this price is subsidized by the manufacturer. The true cost is believed to be twice that of a conventional vehicle (op.cit.).

4.6.1.4 Lower Weight Structural Materials

Lowering the weight of the materials used in vehicle construction allows reductions in engine size without performance loss. There are a number of constraints governing the choice of material used for vehicle structures including manufacturing process technology, surface finish requirements of the automotive industry, behaviour in crash tests, and repairability. Possible materials include aluminium, structural plastics and carbon fibre. Structural plastics and carbon fibre are already in use in Formula One cars and in a few specialist sports cars (Wells 2001 cited in Fergusson 2001). Recent advances have allowed Ford to build a lightweight prototype mid-sized car weighing just 900kg compared with a typical weight of 1450kg (IPCC, 2001). Ford's P2000 aluminium body is 55% lighter than the conventional equivalent (Fergusson, 2001). Weight reductions of 30%, therefore seem possible and with engine downsizing accordingly, 20% fuel economies could be achieved. Light-weight cars are already on the market e.g the Audi A8, which has an aluminium space-frame, the Audi A2 and

Honda NSX which have aluminium unitary bodies, and the Ford Think which is constructed from multiple materials (Wells 2001 cited in Fergusson 2001).

The key problem with use of aluminium as a substitute for steel is that it requires more energy to produce. Recycling of aluminium auto bodies is also more difficult than recycling steel with current recycling technology. Bouwman and Moll (1999) estimate that 85% of vehicle life-cycle energy requirements occur when the vehicle is in use; 15% is used for vehicle production and 3% is recovered in recycling. Because production energy requirements are small in comparison with running energy requirements, use of aluminium bodies is likely to produce an overall reduction in lifecycle energy use. However, the size of this reduction is dependent on several key assumptions, in particular the operational life of the vehicle versus lifetime vehicle mileage. Estimates of the time before fuel economy savings match the increased energy required in production range from 4 to 33 years when compared with a variety of different vehicle body constructions (IPCC, 2001). Bouwman and Moll (1999) found that if aluminium passenger-car bodies were introduced in Holland from 2000 onwards, by 2050 energy savings of 17% were achieved compared with an all steel scenario.

4.6.2 Emissions Reduction

4.6.2.1 Low No_x Burners

Low NO_x burners can be used to limit the emissions of nitrogen oxides. They work through the careful regulation of the combustion to eliminate hotspots (periods of time when combustion reaches 1500C, a key temperature for NO_x formation), to keep the fuel burning uniformly and to keep flame temperature down to a minimum.

4.6.2.2 Lean Burn Engines

Lean burn occurs when surplus air to fuel is used in combustion, i.e. at ratios greater than 14:1. Lean mixtures burn hotter than fuel-rich mixtures and usually produce more NO_x. They do, however, reduce the amount of carbon monoxide and unburnt hydrocarbons emitted. A careful balancing act is required to minimise the different emissions. Lean burn petrol engines typically use an air to fuel ratio of 18:1 (Everett, 2003). At lower ratios the levels of NO_x emissions are higher, whilst at higher ratios fuel consumption and the levels of unburnt hydrocarbons emitted start to increase.

4.6.2.3 Catalytic Converters

Catalytic converters are fitted to most (all) petrol vehicles sold in the EEC since the late 1980s. In the standard 3-way catalytic converter, exhaust gases are past through a chamber containing a ceramic substrate coated with three catalysts: platinum and pallidum, which oxidize hydrocarbons and convert carbon monoxide into carbon dioxide; and rhodium, which separates nitrogen oxides into its component parts of nitrogen and oxygen. Catalytic converters only work when they are hot and they need a slightly rich air-to-fuel mixture. One-way catalytic converters, which oxidize hydrocarbons, are available for diesel engines (Everett, 2003).

4.6.3 Alternative Fuels

4.6.3.1 Liquid Petroleum Gas

Liquid petroleum gas (LPG) is a component of crude oil; its primary constituents are propane and butane. It is highly volatile but can be compressed into a liquid at very low pressures. As a liquid it has similar properties to petrol and can be used in a standard spark-ignition engine with few adjustments (Fergusson, 2001). Most LPG vehicles are dual-fuel. This means that an alternative fuel tank is needed but has the advantage that the vehicle can be used in areas where LPG is not available. This has helped the uptake of LPG, as a comprehensive distribution of refuelling stations is not required.

LPG produces 8% less carbon dioxide than petrol and less NO_x and particulates than diesel (*op. cit.*). These benefits have gradually been eroded by efficiency improvements to petrol and diesel vehicles and the introduction of emissions controls.

The UK LPG vehicle fleet was approximately 39,000 vehicles at the end of 2000 (*op. cit.*). This was expected to rise substantially over the next few years to 1% of the vehicle fleet by 2005 (Fergusson, 2001). The penetration of LPG is limited to around 5% of the diesel- and petrol-powered share of the vehicle fleet, as LPG is only a small component of crude oil.

4.6.3.2 Natural Gas

Natural Gas needs to be liquefied (LNG) or compressed (CNG) to be used for transportation. Either way, bulky storage tanks are required, which limits the range of the vehicle compared with diesel. Specialist refuelling infrastructure is also needed (Fergusson, 2001). Refuelling also takes longer and is more complicated than for petrol and diesel. These factors limit the deployment of LNG and CNG to vehicles such as buses, delivery vehicles and municipal fleets. These vehicles are larger, so have more space for storage, can be refuelled at a single point and tend to travel shorter distances along fixed routes and are parked overnight at depots – all making it easy to install the refuelling infrastructure, as only a single refuelling point is needed, and to sort out refuelling schedules (*op. cit.*).

The environmental benefits of LNG/CNG are greatest compared to heavy diesels. Use of LNG/CNG results in a reduction in NO_x and particulate emissions (*op. cit.*). CNG vehicles are also less noisy than heavy diesel engines.

There are currently 300 LNG/CNG vehicles in use in the UK (Fergusson, 2001). The costs of these vehicles are high. The UK Government now provides funding for both LNG/CNG infrastructure and vehicles via the POWERSHIFT scheme, so uptake is likely to increase. Even with this increased uptake, Fergusson (op.cit.) suggests that LNG/CNG will only account for a few percent of heavy vehicle fuel consumption and less than 1% of total transport fuel demand.

4.6.3.3 Hydrogen

Hydrogen is likely to be mainly used in fuel cells, although liquefied hydrogen could be burnt directly in a modified ICE. One vehicle manufacturer is pursuing the latter option (Fergusson, 2001) and there are demonstration vehicles in use in the UK. Burning hydrogen with air will produce water vapour and some oxides of nitrogen (NO_x) emissions. Fergusson (op.cit.) argues that financially and environmentally this use of hydrogen makes little sense. Energy is lost reforming the fossil fuels to hydrogen, and through cooling the hydrogen for liquifaction. The hydrogen is then burnt inefficiently in an internal combustion engine. The hydrogen needs to be stored in large tanks and refuelling infrastructure needs to be in place. It could be argued that hydrogen combustion forms a stop-gap measure, accelerating the development of hydrogen refuelling infrastructure ready for the uptake of fuel cell technology and allowing vehicle manufacturers and operators to gain experience of onboard hydrogen storage. However, as Fergusson (*op. cit.*) points out demonstration fuel cell powered vehicles will also achieve these things.

Hydrogen could also be added to natural gas (referred to as hythane – a blend of hydrogen and methane) without noticeable effects at a concentration of 10-15% (Boyle, 2003).

Fuel cells potentially enable higher vehicle fuel efficiencies -- approximately double the efficiency of an ICE due to high part-load efficiencies (Boyle, 2003). Fuel cell efficiencies are in the order of 52% if stored hydrogen is used, 35% using a methanol reformer and around 30% using a petroleum reformer (DeCicco and Delucchi, 1997). Greenhouse gas emissions are dependent on the fuel reformed and the process used to produce the hydrogen, i.e. whether coal, oil or natural gas is reformed and whether an in-vehicle reformer is used or hydrogen is produced in large-scale centralised facilities. Shell Global Solutions estimated the "well to wheel" energy use and greenhouse gas emissions for a number of fuel cells (see table 4.6) based on the assumption that the hydrogen would be generated from steam reformation of natural gas using electricity generated from burning fossil fuels (Fergusson, 2001). However, if the reformation is done in large centralised facilities then the CO_2 can be captured, although this could add 25% to the costs of the hydrogen production if the plant is purpose built (Boyle, 2003).

Fuel	**Technology**	**Energy ($MJkm^{-1}$)**	**GHG (gkm^{-1})**
Gasoline	ICE	2.84	220
Diesel	ICE	2.07	152
Hydrocarbon	Fuel cell	1.70	135
Methanol	Fuel cell	2.15	117
Compressed Hydrogen	Fuel cell	1.84	109
Liquid Hydrogen	Fuel cell	2.32	139

Source: Shell Global Solutions (Fergusson, 2001)

Table 4.6: 'Well to Wheel' Energy Use and GHG emissions for different vehicle fuels

Hydrogen is the cleanest fuel option, particularly when local air quality is of concern. However, there are technical and economic problems associated with onboard reformation and storage of the hydrogen and currently no distribution infrastructure is in place (DeCicco, 2001). Storage containers for hydrogen are bulky and thus take up a large amount of space on the vehicle. For this reason, the first applications of hydrogen for powering vehicles have been buses. This also negates some of the refuelling infrastructure problems as only one refuelling point is needed (the bus depot). There are also concerns about the safety of handling such a highly volatile substance as hydrogen, however, the IEA (1999) have assessed that the risk from hydrogen is no more overall than for other fuels used by vehicles.

Hydrogen Source	Cost (US$/GJ)
Natural Gas (small scale)	11-12
Coal/Oil	10-12
Pyrolysis of Biomass	9-13
Hydroelectric power	10-20
Wind power	20-40
Solar power	50-100

Source: Padro and Putsche, 1999

Table 4.7: The costs of different sources of hydrogen

The cost of fuel cells have dropped dramatically in recent years, but are still ten times as expensive per kW as spark ignition engines (IPCC, 2001). The costs of hydrogen vary considerably depending on the source (see table 4.7). Boyle (2003) suggests that the cost of hydrogen could be competitive with petrol in the UK (and other places) where the fuel duty is high.

4.6.3.4 Biodiesel

Around 1.5 million tonnes of biodiesel are produced annually worldwide (WEC, 2001). Commercial biodiesel processing plants using the inter-esterificiation of triglycerides have been developed in a number of countries, with the largest plant having a capacity of 120,000 tonnes (IPCC, 2001). Korbitz (1998) estimates that for every unit of fossil fuel input into the conversion process, over 3 units of energy in biodiesel are produced. Currently biodiesel production costs exceed those of fossil diesel refinery costs by a factor of three to four. This is because of high feedstock costs. Scharmer (1998) suggests that biodiesel is unlikely to become cost effective before 2010, unless supported through taxes and subsidies, or internalisation of oil's environmental externalities occurs. Hamelink *et al* (2004) estimate that diesel derived from biomass via gasification (using the Fischer-Tropsch process) could be produced at a moderate scale in the short-term at a cost of 16 per GJ and at 9 per GJ in the longer term, with reductions in production costs gained from economies of scale, technological learning and through use of selective catalysts. Fischer-Tropsch biodiesel is already being produced in Germany by Choren.

Biodiesel has low sulphur and particulate emissions. High levels of nitrous oxide emissions are, however, caused from fertilisers used during cultivation. Vehicle engines need minor modifications in order to be able to run on biodiesel.

Currently, for the UK the most promising biodiesel is Rape methyl ester (RME) produced from rapeseed oil, although it can also be made from used vegetable oil (Fergusson, 2001). Current fuel duties in the UK support the use of biodiesel. In April 2002 the duty on a litre of biodiesel was 25.82p compared with 45.82p per litre of diesel. However, the uptake of biodiesel is likely be limited by supply, substituting only a two percent of diesel requirements – even if all the set-aside land in the UK were turned over to rapeseed (*op. cit.*). Biodiesel could be imported from other EU countries where there is a greater supply of spare land.

4.6.3.5 Bioethanol

Ethanol is currently produced commercially from sugar cane in Brazil and from maize in the US. It is used either neat or blended with gasoline and has been in use for more than a decade. In Brazil, production of ethanol-fuelled cars has been falling since 1985, when they made up 96% of the market. Currently only 0.1% of cars sold are ethanol fuelled. However, ethanol consumption has continued to increase due to the market for blended fuel. In 1997/8 ethanol accounted for 43% of total fuel consumption in all Otto cycle engines (IPCC, 2001). Research into methanol production from woody biomass has shown energy conversion rates to be around 50% at a cost of USS0.22/litre. Rosa and Riberio (1998) question whether use of ethanol and methanol for transport fuels is the best use of biomass as the energy density of ethanol and methanol is considerably less than that of petrol (65% and 50% respectively).

Ethanol from wheat or sugar beet suffers from the same problems in the UK as for biodiesel, in that supply of these fuels is severely limited by the amount of land available for growing energy crops (Fergusson, 2001). If all available land is used, including set aside, only a few percent of UK motor fuel demand can be met from bioethanol by domestic agriculture. As with biodiesel, ethanol could alternatively be used as a "fuel extender" by blending up to 5% of the fuel with petrol or diesel, without the need to modify the engine (op. cit).

Bioethanol from woody crops could produce between 15 and 40% of the UK requirements for motor fuel (op. cit). This is based on the assumption that 11% (2 million hectares) of UK agricultural land is turned over to these crops. If the most productive of these crops yield 12t per hectare per year then the total resource would be in the region of 24Mt per year. If the energy yield of these crops is 5500 kWh per tonne, then assuming a mass conversion of 75% (mass conversion rates of this order have not yet been demonstrated), this produces 100TWh per year (op.cit.).

Energy crops grown in the UK for conversion to biodiesel and ethanol could be supplemented by imports and by plant-based waste materials (Fergusson, 2001), substantial quantities of which are generated each year (see the above section on biomass for more details).

4.6.4 Heavy Goods Vehicles

As well as the improvements already discussed above, such as direct-injection engines and hybrid vehicles, options for energy efficiency improvements in heavy goods vehicles include: increased peak pressure, insulation of combustion chambers, recovery of waste heat, and friction reduction (improved aerodynamics, lower rolling resistance tyres and reduced tyre weight) (IPCC, 2001). If these were used in combination, a 60% improvement in fuel economy over current levels could be achieved.

4.6.5 Soft Measures

There are a variety of soft measures that can be used to influence travel behaviour and therefore the energy consumption due to transport. These measures can include one or several aspects of travel behaviour, e.g. the number of trips a person makes, the mode used and the distance travelled per trip made.

Fiscal measures which can be implemented by Local Transport Authorities include congestion charging and workplace parking levies. Local Transport Authorities were given the powers to implement these schemes in the Transport Act (2000). To date very few local authorities have made use of these powers. There is a congestion charging scheme in operation in Central London, and Durham charges a small fee for motorists to enter the peninsular area of the city. No local authority to date has made use of the powers to apply a levy on workplace parking. Because of this lack of schemes in operation the evidence on the savings that can be achieved through implementation of these measures is sparse.

Estimates suggest that congestion charging could increase public transport (PT) usage by 15% on route-based schemes such as the one trialled in Leicester and a 10% increase in public transport trips from cordon-based schemes depending on initial traffic conditions and the amount of the charge, amongst other factors (Balcombe *et al*, 2004). As public transport is generally a more energy efficient mode per passenger-km than private transport (Hughes, 1993), this switch to public transport from the car is likely to result in energy savings.

Estimates of the effect of a workplace parking levy on mode split range from a 1% increase in public transport trips to a 20% increase in peak trips by public transport (Balcombe *et al*, 2004). Cooper *et al* (2001) modelled a number of different measures for Belfast and found that workplace parking levies would result in a 19% increase in public transport passenger mileage. A report by ROCOL (2000) suggests that if a workplace parking levy were introduced in London this would result in only a 1% increase in public transport trips. However, use of public transport in London for the daily commute is already very high and parking in the central area is limited. In Milton Keynes parking is plentiful and for most employees free of charge, so one would expect the effects of a workplace parking levy applied to the city to have a much larger effect than found for London.

Land use planning measures can also be used to change people's travel behaviour. Newman and Kenworthy (1989, 1991, and 1999) showed that there was a relationship between density and transport fuel consumption. ECOTEC (1993) found relationships between density and mode split and between settlement size and mode. Balcombe *et al* (2004) shows that these relationships have persisted over time, with generally the larger the settlement the fewer trips made by car and the greater the number of trips made by public transport. Owens (1992) explains that this relationship is due to the greater concentration of housing and facilities in larger settlements which maximises accessibility to public transport routes.

Other factors include the location of the population in relation both to the transport networks and to facilities. Mixed-use developments can encourage non-motorised modes as facilities are within working distance of the home. Other measures include the substitution of trips through use of telecommunications, pedestrianisation of streets and provision of park and ride facilities.

Finally, urban form is related to travel behaviour. The compact city is frequently cited as being the most efficient urban form (see for example Jenks *et al* (1996) and Williams *et al* (2001), although some critics dispute this (e.g. Breheny, 1995). Simmonds and Coombes (2001) found that applying the compact city model to Bristol for new development resulted in a slight increase (<3%) in public transport trips. A study by Rickaby *et al* (1992) found a 2% variation in mode split between different urban forms, when applied to new development in an archetypal British city. The low levels of change concluded by both these studies reflects the slow turnover of building stock and the even slower rates of change of infrastructure. Titheridge *et al* (2001) in a study of Leicestershire found energy savings for intensification (building at increased densities within the current boundaries of the urban area) of towns in the order of 3%.

Chapter Five

ASSESSMENT METHODOLOGY

5.1 BACKGROUND

A wide variety of decision support tools is available to decision-makers to enable them to assess the sustainability of an activity or action. These range from tools which essentially provide the decision maker with information (such as indicators, geographical information systems and environmental statements), to tools which process that information using a set of clearly defined rules to provide a definitive answer (i.e. those which identify the best performing option from a range of options). The latter include tools for life-cycle assessment, cost-benefit analysis and multi-criteria analysis. These, however, are still a long way from being able to handle the complexity of an urban system and are usually limited to optimizing over only two or three parameters.

Those tools which simply supply information tend to incorporate a framework for presenting the information. The use of a framework ensures that all aspects are covered that should be included in the decision and provides consistency between analyses. Some of these tools incorporate methods of analysing data to generate additional information. These include, for example, simulation models, forecasting techniques and overlay techniques.

Many decision support tools also include a method for selecting an option (i.e. for making a decision). This is usually achieved by processing the information to arrive at a single value for each option, but it can also be achieved through provision of a series of rules that 'weed out' options with unacceptable outcomes and/or lead to an 'optimum' solution.

Assessment methodologies can also be distinguished by a number of other characteristics. Fischer (2002) identified four methods for classifying strategic environmental assessment methods: (1) by the level (or tier) of decision they are suitable for assessing: plan, programme, or policy; (2) by the sector for which they have been developed; (3) by how much the tool is integrated into the general decision making processes; and (4) by the scope of the assessment, i.e. whether the tool only considers a limited number of impacts related to the biophysical environment or additionally includes social and economic impacts. Boothroyd (1996) divides policy assessment methodologies into four categories: informal positivistic, formalised positivistic, informal heuristic and formalised heuristic. He distinguishes between positivistic and heuristic methodologies, on the basis of the overriding goals of the methodologies and the consequential compromises that are made to reach these goals. Positivistic assessments strive for precision and replicability, compromising on the holistic to achieve these. Heuristic assessment methodologies place a greater importance on the processes involved than on the ability to accurately model or measure impacts and are more aligned with sustainable development perspectives. The distinction Boothroyd (op cit) draws between informal and formal assessments is in the degree to which policy assessments are regulated; this covers both the circumstances under which a policy assessment is required and degree to which the methodology to be used in assessments is specified.

These classifications are useful in helping discriminate between assessment methods and in selecting the most appropriate tool for a particular set of circumstances. Kreske (1996) suggests that the choice of assessment methodology should be appropriate for the topic and the amount of information and resources (time, money to undertake the assessment) available. Kreske (*ibid*) also suggests that the extent to which a methodology is accepted by the scientific community and in the particular topic area should be a further consideration.

5.2 Assessment Methodologies

The following sections give a brief overview of a number of assessment tools. The list included here is by no means exhaustive but is intended to cover the most commonly used tools and be illustrative of the variety available.

5.2.1 Environmental Assessment (EA)

Also known as environmental impact assessment or environmental impact appraisal (EIA), this method of assessment has its origins in the United States National Environmental Policy Act (NEPA) of 1969, which required an environmental assessment to be undertaken for all actions that have significant impact on the environment. Although policies could be covered by this act, in practice assessment has only been required for large-scale projects including new power plants and other energy-related activities such as mining (Webb and Sigal, 1996; Therivel *et al*, 1992; Glasson *et al*

1994). Early environmental assessments were project- and site-specific and were limited to the biophysical or natural environment.

There are a variety of definitions of environmental impact assessment in the literature but in essence it is a process which involves a number of stages – a scoping study to determine the breadth and depth of the appraisal of the impacts; the appraisal itself – involving the prediction of impacts, the evaluation and assessment of their significance and discussion of mitigation measures; production of a report (commonly referred to as an environmental impact statement or EIS); and a monitoring and review stage (see for example Glasson *et al*, 1994; Wathern, 1988b). The terms assessment and appraisal are sometimes used interchangeably. However, the convention adopted in this thesis will be that of Glasson *et al* (1994), i.e. to use the term assessment to describe the overall process including monitoring and review mechanisms and to use the term appraisal when referring to methodologies and techniques for capturing or producing information on individual impacts.

Many environmental impact assessments make use of an appraisal framework to guide the appraisal process and/or display the findings of the appraisal. The framework for the appraisal can vary from a simple checklist of impacts against which a project is assessed to more complex matrix approaches such as the Leopold matrix (Leopold *et al*, 1971). Other appraisal methods include systems diagrams, simulation modelling, life cycle analysis, cost-benefits analysis, multi-attribute trade-off analysis and energy balance assessments. For the appraisal to take place data needs to be produced to feed into the framework. This data can be gathered or produced using a variety of techniques. These include modelling and contingent valuation techniques.

5.2.1.1 Strategic Environmental Assessment

Environmental assessments conducted on policies are commonly referred to as strategic environmental assessments (SEAs). However, Therivel *et al* (1992) define strategic environmental assessment as:

> *"...the formalised, systematic and comprehensive process of evaluating the environmental effects of a policy, plan or programme and its alternatives, including the preparation of a written report on the findings of that evaluation, and using the findings in publicly accountable decision-making." (Pp 19-20)*

Thus, Therivel *et al* (1992) exclude strategic environmental assessments that do not influence the decision, examine alternatives or produce a written report. In addition, policy-making processes which incorporate environmental objectives in an integrated approach but do not involve a formal environmental assessment would not be included in this definition.

Environmental assessment has expanded to include the impacts on the built or man-made environment and in a few cases to include economic and social aspects within the assessment. However, in the vast majority of cases the main emphasis is on appraisal of the biophysical environment. Fischer (2002) assessed 25 SEAs conducted for 36 policies, plans and programmes across three European Regions – North West England, EVR Brandenburg-Berlin and Noord-Holland -- in the policy areas of land use and transport. He found that while most of the SEAs provided reasonable coverage of environmental impacts under 7 headings (fauna, flora, soil, water, air and noise, climate, landscape and cultural heritage), very few covered socio-economic aspects to any significant extent and even fewer quantified these aspects. In North West England only one of the 7 SEAs directly appraised socio-economic impacts, and that was limited to only two impact categories (public service and fiscal considerations) although other aspects were indirectly assessed. None of the SEAs assessed in any of the three regions directly appraised all 7 socio-economic impact categories (economy, population, housing, public service, fiscal, income and social impacts) although one – Vision Hilversum – directly assessed 6 of the 7 categories qualitatively and indirectly covered the 7th (housing).

Bruhn-Tysk and Eklund (2002) reviewed a number of environmental impact statements for Swedish biofuelled energy plants. They found that global effects of the energy plants were not assessed and societal aspects of sustainable development were not addressed. Aspects of inter-generational equity were also not included in the statements.

Recent developments in this field have tended to focus on the overall process, improving the level of integration of the EA process within the general decision-making process (Nilsson *et al*, 2004). Less attention has been paid to improving the appraisal framework or the choice of techniques for assessing individual impacts.

5.2.1.2 Social Impact Assessments

Social impact assessments are closely related to environmental assessments. Burdge and Vanclay (1995) define social impact assessments as a "*process of assessing or estimating in advance, the social consequences that are likely to follow from specific policy actions or policy development*" (p32). Here also the emphasis is on designing a decision aid that is integrated into the policy process. Social impact assessments tend to be carried out for projects and policies which are thought to affect the indigenous population. There are several examples of social impact assessments being conducted for energy-related projects, such as the construction of dams, oil pipelines and mining activities (*op.cit.*).

Assessments vary in scope but cover aspects such as the effect of the project or policy on the livelihood, culture and heritage of the indigenous population. Burdge and Vanclay (1995) define social impacts as:

> *"all social and cultural consequences to human populations of any public or private actions that alter the way in which people live, work, play, relate to one another, organise to meet their needs and generally cope as members of society." (p32).*

Vanclay (2000) discusses several different classifications of social impacts including: the classification of Armour (1990), who looks at way of life, culture, and community; that of Vanclay (1999), who additionally covers political systems, environment, health and well-being, personal and property rights, fears and aspirations; that of Juslen (1995), who discusses social impacts such as noise, pollution etc., but also includes psychological impacts, anticipatory fear, the impacts of carrying out the assessment itself, impacts on state and private services, and impacts on mobility; and that of Burdge (1994) who includes demographic effects, public involvement, conflicts between local residents and newcomers, cultural effects and infrastructure needs.

5.2.2 Life-Cycle Assessment or Life-Cycle Analysis (LCA)

Gagnon *et al* (2002) define life-cycle assessment as an environmental assessment of "all the stops" involved in the creation of a product. It includes all significant impacts that can be quantified, at all stages of production and post-production – hence the term 'life-cycle'. In the energy sector, the assessment would include fuel extraction, processing and transportation; plant construction, operation, decommissioning, and waste disposal.

Few LCAs attempt to include social impacts. There are a few attempts, particularly when comparing technologies such as renewable energy technologies, to include aspects such as reliability of supply in the analysis, usually by including storage facilities in the assessment.

The methodology can be either site-specific or product-specific, mapping actual chains in the production/construction process. Additionally, the methodology has been used for the assessment of technologies at a generic level (see for example Lee, 2002; Waku, 1995; Widiyanto *et al*, 2003; Govokhov *et al*, 2002; Navrud, 2001; Sarigiannis and Triacchini, 2000; and Besnainou and Sheehan, 1997). Nilsson *et al* (2004) use the technique for assessing waste incineration taxation policy. This achieved by assuming general or typical values for the various components of the assessment. Gagnon *et al* (2002) illustrates how widely assessment results can vary for different electricity generating technologies depending on the assumptions made in the assessment processes. In a review of recent literature Gagnon *et al* (op cit) found, for example, that the land requirements to produce a TWh of electricity from biomass production ranged from 533 to 2200 km^2.

Many technology LCAs produce inventories of emissions rather than trying to give an actual description of the final environmental impacts. This is because of the extreme variability of the impacts, depending on geography, geology and other sources of pollution in the relevant location.

5.2.3 Multi-Criteria Evaluation

In this type of analysis, options are compared on a selected number of attributes. The attributes are weighted to reflect their relative importance before being summed to produce a single value for each option. The methodology is suitable for quantitative data and can also be used for qualitative data by assigning a rank or indicative value. The methodology is not well suited to dealing with issues such as data quality, uncertainty, risk or equity.

As with life-cycle analysis, the technique has largely been applied to date to the evaluation of different technologies. Afgan and Carvalho (2002), for example, compare ten power plants using such attributes as energy resources, environmental capacity, social and economic indicators. Afgan *et al* (1999) compare a number of energy supply systems for a small island. Yelda and Shrestha (2003) use the approach to compare three alternative transport options: 4-stoke 2-wheelers, CNG cars and CNG buses for Dehli. Xiangjun *et al* (1999) have developed a multi-criteria decision tool for planning the expansion of regional power generation systems.

5.2.4 Modelling

Models provide a means of predicting the effects of an action and are particularly useful when dealing with complex systems involving many variables and interactions. In the energy field, a number of models have been developed including: TEMIS, a model developed by the Oko-Institut and the University of Kassel, Germany for assessing energy policy at the national level; EEP (Energy and Environment Prediction), a model developed by the University of Wales, Cardiff (University of Wales Cardiff, 2004); and DREAM (Dynamic Regional Energy Analysis Model) developed at the Open University (Boyle *et al* 1994; Boyle, 1996).

Models can be divided into those which take a top-down approach and those taking a bottom-up approach. A top-down model uses as its starting point an overall description of the behaviour of the system being modelled, whilst a bottom-up model uses the basic components of the system as a starting point and builds these up into a model of the whole system. Top-down models are generally used to model energy-economic systems at the macro scale (national or higher), whilst bottom-up models are more likely to be used to model regional or municipal energy systems (Dooley *et al*, 2003). Models vary considerably in the level of detail incorporated into the model and there are usually trade-offs between the resources required to set up and run the model and the quality of the output. The quality of the data generated by a model is dependent on the input data (for example, how it was collected, its scope), the theory on which the model is based (its robustness, predictive power and relevance) and the implementation of the model as a computer program (Tweed & Jones, 2000; see also Groscurth and Schweiker, 1995). Models have been criticised for presenting output data at a much higher precision than is appropriate and for their inability to handle uncertainty.

5.2.5 Multi-Attribute Trade-Off Analysis

Multi-attribute trade-off analysis takes modelling one step further and attempts to clarify and present visually the information from scenario modelling. Several stages are involved:

1. The criteria by which the strategies are to be assessed are selected. There is no limit to the number of criteria that can be selected, but the more that need to be assessed, the more time-consuming and complex the process. Assessment is usually done by a group of policy makers but there is no reason why an existing set of sustainability indicators or objectives could not be used. By selecting the criteria before any modelling of the strategies occurs, selection is less likely to be biased toward a favoured strategy.

2. A set of scenarios describing possible futures are chosen. In the case of energy policies for cities the futures to be considered might include low and high economic growth, rapid population expansion, or declining population. Including a variety of futures enables the range of risks to be assessed.. As with the criteria, there is no limit to the number of scenarios that can be selected.

3. Each of the scenarios for each future is modelled. During this stage, better combinations of projects might become evident, or other possible scenarios. The modelling may show that one or more of the assessment criteria are unnecessary. These can then be discarded and the strategies refined.

4. The outputs from the modelled scenarios are assessed according to the criteria. A series of graphs are produced, each graph comparing all of the possible combinations of futures and strategies the fulfil two of the criteria.

Multi attribute trade-off analysis is a good way of narrowing down the options. However there is a tendency for the method to get complex and cumbersome if large numbers of strategies, criteria and scenarios (futures) are involved. It is perhaps better to stick to 3 scenarios (high, low and expected values) and a small number of assessment criteria (e.g. cost, 6 main air pollutants, and total fossil fuel consumption).

5.2.6 Indicators

Indicators are used where a concept (or political goal), such as sustainability, quality of life or social inclusion, is difficult to define in such a way that it can be operationalized. Indicators are a series or set of data that give an indication of the concept. There are many different sets of sustainability indicators in use and suggested in the literature, with sets of indicators being generated for different cities, regions or nations, for different policy areas and for different purposes. For example, Seattle has developed a set of 40 sustainability indicators for use by both local citizens and policy-makers to monitor progress towards sustainability and encourage appropriate behavioural changes. The indicators are tailored to local circumstances and include, for example, the population of local wild salmon as a measure of the quality of the natural environment (Sustainable Seattle, 1998). Afgan *et al* (2000) use a set of sustainability indicators that are specifically tailored to the assessment of energy systems.

A number of criticisms of indicators have been made: that they potentially over-simplify complex systems; that not everything can be quantified; that in some cases the indicators have become the objective rather than the means of monitoring progress towards an objective; that the selection of indicators can be open to biases; that the interpretation of a suite of indicators can be difficult (some sets of sustainability indicators contain over 100 separate indicators); and that we may not know what is a sustainable level – for example, (referring back to the Seattle example mentioned above) whether a particular population of local wild salmon is sustainable in the long term: too many fish may place a strain on other parts of the ecosystem; too few, and the population is in danger of being wiped out. These criticisms have been addressed in the literature by the production of criteria for what an indicator should be. Bell and Morse (2003) suggest that an indicator should be specific, measurable, usable, sensitive, available and cost-effective. Hager & Meyer (1996) suggest a similar list but also emphasis the timeliness of the indicator, i.e. it must be measured regularly and react quickly to change: an indicator which does not show the effects of an action until many years after the action took affect is not very useful for prompting policy changes.

Inevitably, any sustainability appraisal will need to rely to some extent on indicators in order to reduce the amount of data required to manageable levels and because not all of the concepts that would need to be included in such an appraisal are simple to define.

5.2.7 Game Theory

This method of analysis was first developed by Von Neumann and Morgenstern (1947) for economic assessments (Hill *et al*, 1978). For each option under consideration, the decision-maker tries to determine the possible counterstrategies that any rivals may take in response, and the outcome of each. A matrix display is made of the outcomes of all possible strategies and counterstrategies. The choice of strategy can then be based on selecting the strategy which has the lowest risk of failure, or the least risk of catastrophic failure if failure occurs, or on some other decision rule.

5.3 Experience of Policy Assessment within the Energy Sector

Within the energy sector there are very few examples where full sustainability assessments of energy policies have been undertaken. Therivel *et al* (1992) recognise the importance of assessing energy policy in their book on strategic environmental assessment by devoting a chapter to the energy sector. However, they found very little evidence of systematic environmental appraisal of UK Government energy policies or regional energy strategies. For example, a study of renewable sources of energy in the North-West by Norweb only examined the environmental impacts of each technology "on limited and non-standard criteria" (*op. cit.* p103). There is evidence of strategic environmental assessment (SEA) being carried out on energy policies elsewhere in Europe, for example Kleinschmidt and Wagner (1996) discuss an SEA of wind farms in the Soest District of Germany.

Afgan *et al* (1999) have developed an energy system assessment framework using multi-criteria evaluation of a number of sustainability indicators (for a description of this technique see section 5.3.3 above). The indicators cover resource consumption, environmental, social and economic aspects of energy supply. The indicators are normalised and then aggregated, allowing a number of options to be compared. Weight coefficients can be applied to reflect the importance attached to a particular indicator. This methodology has only been applied to energy supply systems, using a small number of indicators for which quantitative data is readily available and has as yet only been used in a theoretical context. A major limitation of the approach is the lack of availability of suitable data.

Nilsson *et al* (2004) used three different analytical pathways (a life-cycle analysis pathway, a site-dependent pathway and a qualitative pathway) within a strategic environmental assessment framework to assess a waste incineration tax proposal for Sweden. The qualitative pathway used 15 environmental objectives relating to the natural and built environment; the LCA pathway considered 10 environmental impacts including one on human toxicity; whilst the site-dependent pathway was narrower still in its scope, concentrating on the emissions of sulphur dioxide (SO_2), nitrous oxides (NO_x) and particulates (PM). Impacts from all three pathways were valued using a selection of different methods.

Within the UK, regulatory impact assessments have been carried out on the majority of new regulations since 1998 (Cabinet Office, 2003). However, the regulatory impact assessment (RIA) is primarily concerned with the economic impacts of new regulations. Regulatory impact assessments check for impacts on equity and fairness and sustainable development, and should be considered when calculating the costs and benefits of a policy proposal. Two examples where the impacts of a regulation on the environment have been taken into account are: the assessment of the passenger car regulations 2001, relating to the availability of consumer information on fuel economy and carbon dioxide emissions in relation to the marketing of new cars (DfT, 2002a); and on the draft EU Directive on the use of Biofuels (DfT, 2002b). Both of these policies are directly aimed at reducing carbon dioxide emissions and the impact of climate change. In both cases, these are the only aspects of the environment that have been taken into account in the RIA.

At a seminar in 2002 on sustainability impact assessment (SIA) sponsored by the UK Department for Environment, Food and Rural Affairs (2002), Lowson distinguished SIA from existing tools such as Regulatory Impact Assessment, Business Impact Assessment and Strategic Environmental Assessment. Wilkinson (DEFRA, 2002) at the same seminar questioned the role of SIA given the range of other instruments in use. The UK Government is in the process of introducing a new tool – integrated policy assessment (IPA) which aims to provide a framework into which the myriad of assessment tools currently in use by the UK Government will fit. It aims to reduce duplication of effort as a result of overlap between the different assessment tools. DEFRA (2002) suggest that this tool should fulfil the role of a sustainability impact assessment tool as defined by the Göteburg European Council in June 2001. Such tools are designed to assess national and EU policies and may not be appropriate for assessing policies at the local level.

At the level of the municipality, much energy policy assessment has been conducted using simulation models. As mentioned above, simulation models include TEMIS, developed for assessing energy policy at the national level but since adapted to the city level and applied, within the UK, to Newcastle upon Tyne (1992); the EEP (Energy and Environment Prediction) model (Jones *et al*, 1997; University of Wales Cardiff, 2004); DREAM-city (Dynamic Regional Energy Analysis Model adapted for cities) (Titheridge *et al* 1996a, 1996b), TRANUS (Rickaby, 1991; Rickaby *et al*, 1992) and the Quantifiable City model (May *et al* 1997). These models are generally limited to the estimation of energy and emissions, although other aspects of resource consumption are sometimes included such as water and waste. Models tend to be limited to a few indicators due to the complexity of the systems involved, uncertainties regarding the nature of relationships within the system, and difficulties obtaining all the necessary data.

One area within the energy sector where assessments have consistently been undertaken is environmental impact assessments of new power generation projects (section 5.3.1 gives a description of this approach). Within the United States these are required by the National Environmental Policy Act of 1969 (NEPA). They have been required within the European Community since July 1985 for certain categories of projects including crude-oil refineries, thermal power stations with a heat output of 300 MW or more, nuclear power stations and other reactors. In addition other energy industry projects may be subject to an assessment if so required by the member state (Council of the European Communities, 1985). Many other countries, both developed and developing nations, have also implemented EIA procedures (Wathern, 1988a).

Assessments of energy supply technologies are numerous, although most of these are academic in nature and were not undertaken by policy-makers as a means of selecting which technologies to advocate. The majority of these technology assessments utilise life-cycle analysis techniques (see section 5.3.2 for a description of the technique) to compare the energy consumption and resource consumption the technologies being assessed, see for example Gagnon *et al* (2002). A number, for example Andersson and Jacobsson (2000), also include an economic appraisal. Only a small minority include the social impacts of the technology in their assessment e.g. Hall and Scrose, 1998; Hanegraaf, 1998: Kasai, 1999; and Powell, 1996.

5.3 Experience of Policy Assessment in Other Sectors

Outside of the energy sector, sustainability appraisal has been widely used in the UK at the regional and local authority level; most commonly for appraisal of land-use plans but also increasingly for the appraisal of local transport plans and new transport infrastructure projects. The UK Government recommends sustainability appraisal should be conducted on development plans (DETR, 1998) and regional planning guidance (DETR, 2000). Sustainability appraisal of local development frameworks and regional spatial strategies is likely to be a requirement (ODPM 2003a, 2003b, 2003c). Both these plans will be required to undergo strategic environmental assessment under EC legislation (EC Directive 2001/42/EC) and the UK Government plans to meet this requirement through sustainability appraisal (ODPM, 2004). Strategic environmental assessment is also widely used within these sectors both in the UK and elsewhere (Fischer, 2002). In a number of cases this methodology has simply been extended to include economic and social impacts. UK Government guidance (DETR, 1998) advocates integrating social and economic issues within the environmental appraisal frameworks already in use in Local Authorities. This is the approach adopted by Hertfordshire County Council (2002) for sustainability appraisal of the County's Local Transport Plan amongst others.

5.4 Tool Specification

As shown in the previous chapters, there are a lot of motives to change energy consumption and supply patterns and no one obvious solution. Different policy options need to be compared on a consistent, transparent and objective basis. The methods that have been applied to date within the energy sector are far from ideal. Some are too labour- and data-intensive, others are too open to subjectivity and require too little information to enable a comprehensive assessment. Yet other methodologies are too narrow, concentrating on only very specific environmental criteria. Techniques like life-cycle analysis are more suited to the assessment of a technology than a policy.

If the tool is to be used throughout the decision process (as illustrated in Figure 5.1), rather than as a last check that the chosen energy policy or strategy is acceptable, then it must be easy maintain and use. The easier and cheaper the tool is to set up in the first instance, the more likely it is to be taken up by a user such as a local authority. This ease of use and set-up applies not just to the user interface but also to data requirements, the input format of the data, and the ease with which the output can be interpreted. Obviously, there is likely to have to be some compromise between the ease of use and the quality of the tool's output in terms of accuracy and extent.

Table 5.1 summaries the methodologies described above with respect to the criteria for an energy policy evaluation tool that have been outlined above, namely:

1. Ease of use and extent of experience of using similar techniques with the sector;

2. Ease in setting-up;

3. Ability to handle environmental, social and economic impacts;

4. Ability to deal with the timescale of impacts;

5. Ability to deal with risk;

6. Ability to take equity into account;

7. Ability to clarify the decision process;

8. Extent to which information is provided to the decision maker;

9. Extent to which decision makers are enabled to make judgements rather than having a decision forced on them;

10. The extent to which the scope of the tool can be extended beyond project or site specific appraisal;

11. Ability of the tool to handle large amounts of data;

12. Suitability of the tool for assessing local energy strategies.

Energy models are the most suitable way of comparing a number of different policy strategies on a consistent basis. However, most energy models are limited to calculating emissions; many only calculate carbon dioxide emissions. Other aspects of sustainable development need to be taken into account but many are difficult to incorporate into a model because the potential impacts are a) unquantified, b) the data is unreliable or c) contains a great deal of uncertainty. In addition there is a problem of how to incorporate impacts with a low probability of occurrence. This suggests that the best approach would be to use an energy model to quantify as many impacts as possible, supported by additional quantitative and qualitative data from other sources.

In order to enable consistent comparison of each strategy, data from the energy model and other sources could then be fed into an assessment framework. The framework will need to be able to handle a mixture of data types from different sources as well as cover environmental, social and economic aspects. Because of this need to be able to handle a mix of different data types, use of a tool such as multi-criteria evaluation or multi-attribute trade-off analysis is not practicable, as this would require substantial additional resources to produce a robust set of weightings and/or values for each impact.

Figure 5.1: Energy Strategy Development Process

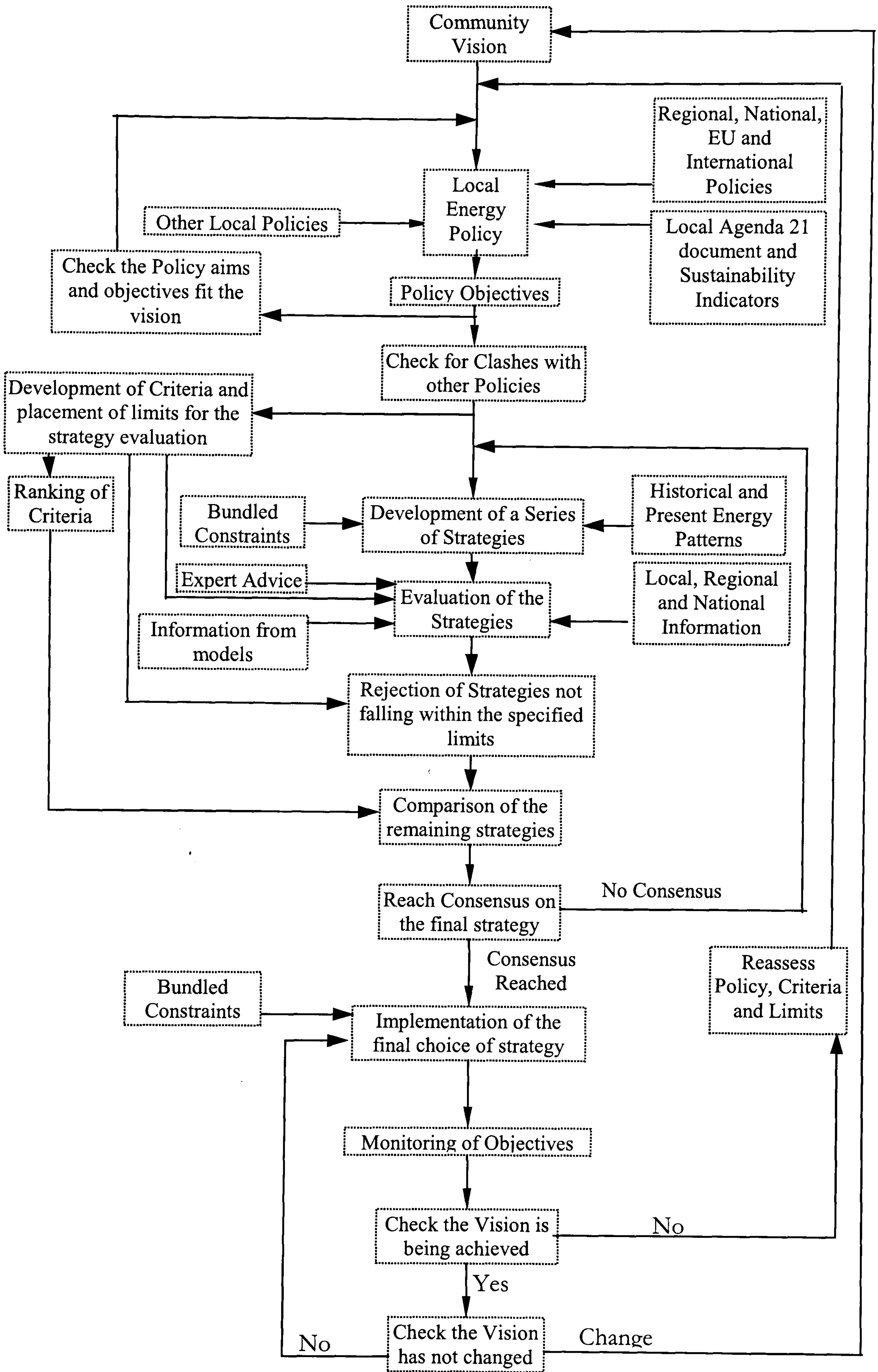


Table 5.1: A Summary of Assessment Techniques

	Information Providers						Decision Makers						
	EIA	IS	GIS	SEA	Modelling	LC Assessment	LC Analysis	CBA	Multiattribute	Matrices	Decision Trees	Rank-ing	Gaming
Easy to Use	√ - provides simple tables ?	√ - if set up correctly	√ - if set up correctly	√ - provides simple tables	? - Varies between models			√ - basic principles okay but choice of benefit valuation technique can be complex	? - data comes from models, presented graphically	√		√	√ - straightforward mathematics
Easy to Set Up		X - v. time consuming, requires large amounts of data	X - v. time consuming, requires large amounts of data		? - usually requires model specifically for the region and type of policies			? - Can need a lot of survey data	? - Modelling may require a lot of setting up	√		√	√ - need info on probabilities of outcomes and probabilities of reactions
Environmental Data	√	√	√	√	√ - particularly air pollutants	√	√	√ - Lots of examples in the literature	√				? - could be adapted to deal with environmental data
Social Data	X - though no reason why the same technique can't be applied	√	√	X - though no reason why the same technique can't be applied	√ - can be dealt with but often neglected	√ - Yes but so far mainly for health and risk	√ - Yes but so far mainly for health and risk	√ - Yes but so far mainly for health and risk	√ - can be dealt with but technique used more often for economic or environmental criteria				? - could be adapted to deal with social issues
Economic Data	X	√	√	X	√ - a lot of economic energy policy models exist	√	√	√ - uses this as basis	√				√ - developed for businesses

	Information Providers						Decision Makers						
	EIA	IS	GIS	SEA	Modelling	LCAssessment	LCAnalysis	CBA	Multiattribute	Matrices	Decision Trees	Ranking	Gaming
Deals with timescale	X	X	X	X	√	√	√	√ - by using discount factor	√ - by modelling future scenarios				? - could be adapted to deal with time
Deals with Risk						X	X		√ - by modelling a variety of futures can deal with risk associated with economic growth etc.				√ - created to deal with risk
Deals with Equity					? - depends on the model but no reason why not	X	X	X - no, gives one total/average figure	√ - depends on how the model and criteria are set up				? - could be adapted to deal with equity issues
Clarifies Decision Process							√ - shows weightings/ relative importance of different impacts		√ - partially	√		√	√ - to some extent
Provides Information	√	√	√	√	√ - information on possible outcomes and information on the system that is not usually otherwise available	√ - in tabular form	√ - if intermediate stages are shown		√ - graphical data on criteria, data from model				X

	Information Providers						Decision Makers						
	EIA	IS	GIS	SEA	Modelling	LCAssessment	LCAnalysis	CBA	Multiattribute	Matrices	Decision Trees	Ranking	Gaming
Allows for judgement					√ - usually models are information providers only	√ - simply provides a table/list of impacts	√ - in weighting of the different assessment criteria	X - gives one final figure on which to make the decision	√ - shows a selection of the "better" options and allows decision maker to choose between them. Also judgement involved in the selection of the initial criteria				√ - shows likely outcomes but still allows decision maker to chose low/high risk options
Project/Site Specific	√				X - doesn't have to be	√ - project and site specific	√ - project and site specific	√ - Mainly but can apply to other policies	X - developed to test strategies				
Large amounts of Data Required		√	√		√ - usually, depends on the level of modelling required	√ - databases exist to help provide some of this information but many of these do not cover local energy policies.	√ - databases exist to help provide some of this information but many of these do not cover local energy policies.	√ - can do depends on the quality of assessment	√ - can do, depends on the complexity of the model, and the number of criteria chosen				

	Information Providers						Decision Makers						
	EIA	IS	GIS	SEA	Modelling	LCAssessment	LCAnalysis	CBA	Multiattribute	Matrices	Decision Trees	Ranking	Gaming
Forces the Decision					X	X - but only provides a choice between accepting or rejecting a proposal	√ - provides a choice between yes, this is acceptable and no, this is not acceptable. Doesn't normally compare different options.	√ - provided with one optimum solution	X	√ - provided with one optimum solution		√ - provided with one optimum solution	X - shows the probability of different outcomes but lets the decision maker chose between high or low risk solutions
Suitable for assessing local energy strategies?					√ -partially				√				

Key: √ - meets the criteria; X - does not meet the criteria; ? – varies depending on the precise methodology used

5.5 Description of Chosen Methodology

The methodology developed enables energy strategies to be assessed in terms of: (i) monetary costs; (ii) quantitative impacts in terms of fossil fuel use and pollutant emissions; (iii) qualitative impacts; and (iv) other impacts that are identifiable but not assessable within an impact assessment framework based on the strategic environmental assessment technique. The methodology combines several components: an energy and emissions model (DREAM-city); an impact database; a monetary cost evaluation spreadsheet and. The SEA technique has been extended to include economic and social impacts.

5.5.1 Assessment Framework

The framework adopted for the evaluation and comparison of the scenarios in this thesis takes the form of a two dimensional matrix. Along the vertical axis is a list of categories to be used for assessing the strategies. These categories act as a checklist. The use of a checklist is designed to encourage wider thinking about the impacts of a strategy and to help ensure all impacts are taken into consideration (SERPLAN, 1996). Ideally these would be selected independently of the strategy development process. The criteria chosen are based on a Department of Environment (1993) listing, which included the following categories:

1. Capital Cost
2. Operation and Maintenance Costs
3. Land Use, Landscape and Open Land
4. Noise
5. Visual Intrusion
6. Transport (energy efficiency, number of trips, modes)
7. Health and Safety
8. Ecology/Wildlife Habitats
9. Job Creation
10. Liveability of Towns and Villages (including Building Quality, Cultural Heritage, Public Access, and Community Involvement)
11. Water Conservation & Quality

12. Resources (including ores, minerals and embodied energy)
13. Emissions of Greenhouse Gases
14. Air Quality
15. Land and Soil Quality

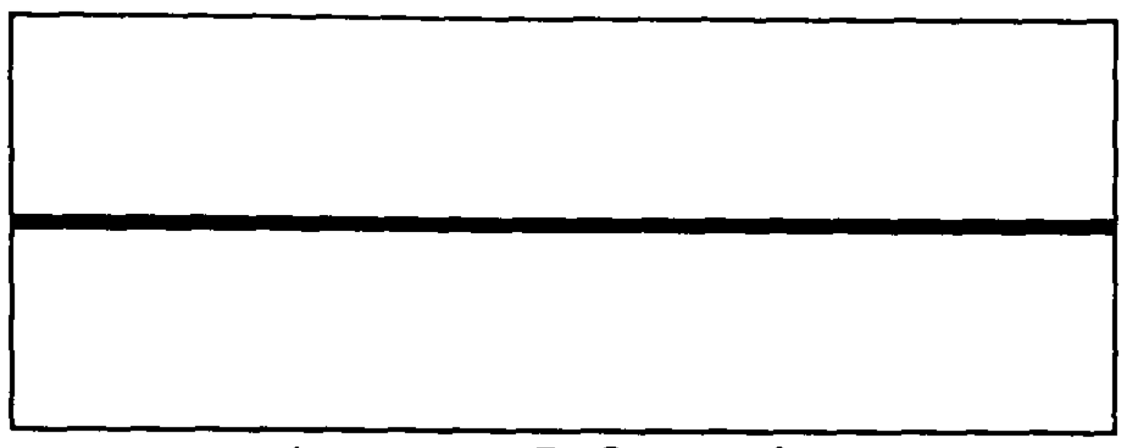
This list was chosen for a number of reasons. It includes criteria relating to both the natural and the built environments, to quality of life and economic costs. The criteria included are not exhaustive but cover a sufficient range for our purposes. A longer list would become difficult to handle, particularly as several of the criteria listed contain sub-criteria. In addition, the list is one which was widely referenced in local authority and central government policy documents and has been used as the basis for strategic environmental assessments of a number of local plans and structure plans (for example: SERPLAN, 1996; Mid-Bedfordshire District Council, 1995; Lancashire County Council, 1993; Kent County Council, 1993; Bedfordshire County Council, 1994). Thus the meaning and breadth of the criteria are well understood within local government – at whom the methodology developed for this thesis is aimed.

The vertical axis is divided by technology type – energy supply technologies and energy demand (efficiency) technologies. This ensures that impacts from both the demand and supply side effects of the strategy being assessed are taken into account.

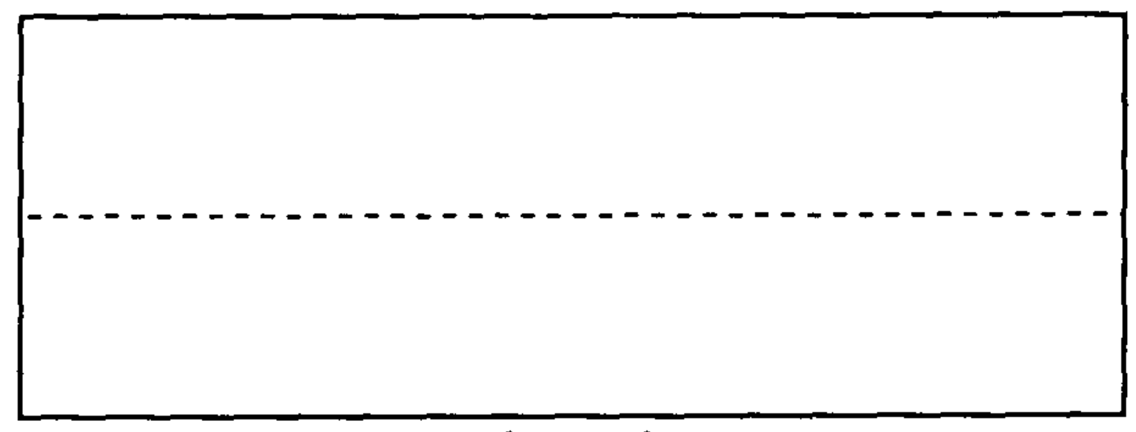
Each cell in the matrix is divided horizontally into two compartments. The top compartment contains information on the size and types of impacts, e.g. monetary cost, resource consumption, tonnes of emissions. Where several different impacts occur under the same heading, cells are sub-divided horizontally. Different coloured text is used to show the source of the information presented (see table 5.2)

The thickness of the line dividing each cell horizontally into the two compartments was used to show the quality of the data being presented, as shown below:

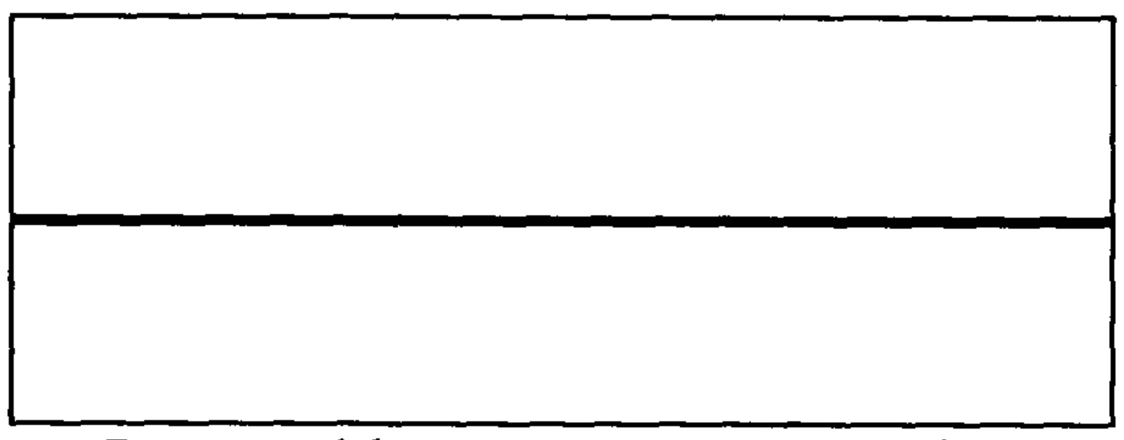
Accuracy of Information



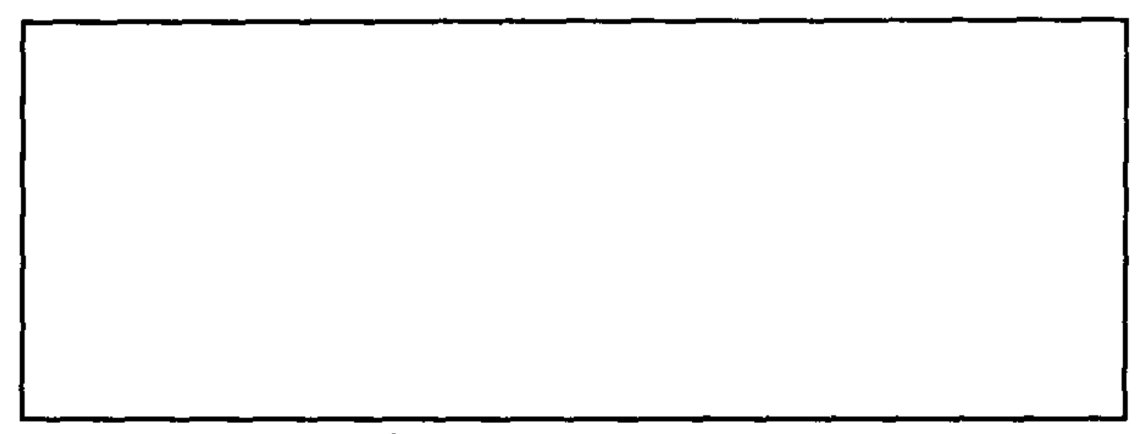
Accurate Information



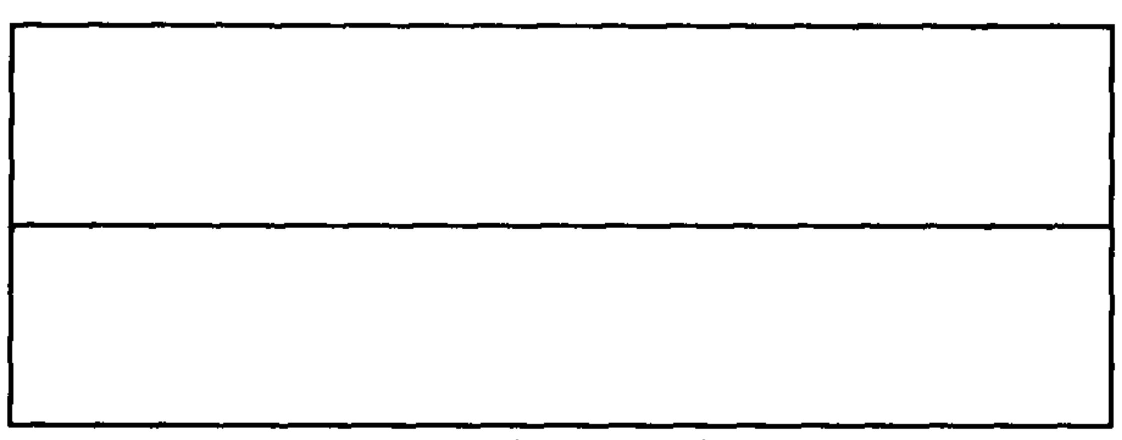
Rough Estimate



Reasonably Accurate Information



Unknown Accuracy



Reasonable Estimate

The bottom compartment contains information on the lifetime of the impact, the probability of occurrence, the spatial scale of the impact, and which sectors of society are likely to be affected. As a visual aid to comparison, a system of letter codes signifying different types of impact was devised. Each set of letter codes refers to a different property of the impact. These are always listed in the same order. From left to right these are:

Impact Lifespan, Probability of Occurrence, Affected Communities.

Impact Lifespan

C during the **C**ommissioning phase
O during the **O**peration phase

D during the **D**ecommissioning phase

M during the **M**anufacturing of the product

A impact continuing to have effects long **A**fter the lifespan of the technology

Probability of Occurrence

P(H) **H**igh probability

P(M) **M**edium probability

P(L) **L**ow probability

P(E) **E**xtremely low probability

P(?) Unknown

Affected Communities

The numbers and types of affected communities are too many and too varied to develop a comprehensive coding system, therefore, a brief description of each affected community will be included in impacts matrices, i.e. miners, workers, local residents.

An extract of an impacts table is given in table 5.2.

	Technology/Project Details						2. O&M Costs			
Technology	Scale	Load Factor	Construction Time	Lifetime	Decommissioning Time	1. Capital Cost	a. Fuel Costs	b. Other O&M Costs	3. Land Use, Landscape and Open Land	4. Noise
		%	years	years	years	£	£/kW/year	£/kW/year		
Wind:										
Onshore	5MW	25 to 40	Installed over 25 years	15 to 25	1	£800 to £1200 per kW, £40,000 to £60,000 total	0	12 to 18	3 to 4 sq km for a 20 turbine farm, actual space used = 1% of this for concrete foundations and service road, typically 10m^2 per kW rated power. Can be returned after decommissioning. Land use negligible	Compliance with Local Authority requirements. Between 35 and 50dB at 350m. Below 35dB a few rotor diameters away. 0.00009DM/kWh based on a 3% reduction in rent values of nearby homes
						C, R(H), Business		P, R(H), Business	CPD, R(H), Rural Communities outside Council Area	CPD, R(H), Rural Communities outside Council Area

Key: Sorenson B (1996) Life-cycle analysis of renewable energy systems, Renewable Energy, Vol 5(2) pp1270-1277, Hohmeyer O (1988) Social Costs of Energy Consumption; Springer Verlag, Berlin. See section 5.5.1 for an explanation of the codes C, P, D and R().

Table 5.2: An Extract of a Completed Impacts Table.

The full impacts tables when completed were likely to be very large and hence would be difficult for the decision maker to absorb the information contained within them. It was therefore felt necessary to also produce a summary table for each strategy assessed. These tables generally followed the same format as the full impacts tables but attempted to précis the impacts listed in the full tables. Transposing the axes in the summary tables made them more manageable and the full width of the table then fitted on to A4 paper. Colours in the summary tables were used to distinguish between different impacts, rather than between different sources of information as was the case for the full impacts tables. An extract of a summary table is given in table 5.3.

		Impacts of Energy EfficiencyMeasures		**Impacts from Fossil and Nuclear Fuels**		**Impacts of Renewables**	
Total Energy Consumption	**Electricity**			114 PJ from National Grid		Nil	
	Gas			309 PJ Natural Gas			
	Oil			137 PJ			
	Solid Fuel			5.5 PJ			
	Total			565 PJ		Nil	
1. Capital Cost	**£(1990) millions**	£106 to £1,147	C, P(H), Businesses and Households	Included in Fuel Costs			
2. O&M Costs	**a. Fuel Costs**	Negligible		£3505 to £3990 million?	O, R(H), Households, Businesses in Council Area		
	b. Other O&M Costs	Negligible		Included in Fuel Costs			
3. Land Use, Landscape and Open Land				Possible use of agriculture land and/or wilderness areas for: a) Coal production b) Siting of new power stations c) New power lines	COD, R(H), Tourists, Rural Communities; COD, R(E), Local Residents CD, R(L), Tourists, Local Communities		

Key: See section 5.5.1 for an explanation of the codes. Colours are used to distinguish between impacts.

Table 5.3: An Extract of an Impacts Summary Table.

5.5.2 The Energy Model

DREAM-MK was chosen as the energy model to use for the calculation of energy consumption and associated emissions, as this model was already set up for Milton Keynes and contained many features required for modelling the effects of energy policies across the sectors.

A description of the model can be found in Chapter 3 and a list of the equations contained within the model in Titheridge (2004).

5.5.3 Impacts Database

A number of existing databases were reviewed, including Eco-Indicator 95 (Goedkoop *et al*, 1996), a database of of materials and processes, the IDEMAT database developed by Delft University of Technology, TEAM by EcoBalance, the UK-based Boustead database and IVAM, a Dutch database which focuses on materials, transport, energy and waste treatment. Many of these were designed for the purposes of carrying out life cycle assessments on a particular product or in a particular country. As such, they tend to contain very detailed information on different production processes and materials, the expectation being that the user would build up the product assessment from a knowledge of the processes and materials that went into the production of a particular product. This requires a much greater depth of knowledge about the technologies that would form part of an energy strategy than a policy maker could reasonably be expected to possess. Another type of impacts database is that constructed for the purposes of evaluating energy policy at a national level, such as the database underlying the TEMIS model. Such databases, whilst including a wide range of impacts on energy supply technologies, include very little on energy efficiency technologies. In addition they tend to concentrate solely on the environmental impacts of a technology.

For consistency purposes across sectors and technologies, it was considered simpler to compile a database from scratch rather than extend or adapt an existing database.

A database was therefore compiled that listed as many impacts as possible of a wide variety of energy-related technologies and actions. The database was compiled from a variety of sources including academic literature, trade publications, and Energy Efficiency Office and Building Research Establishment Best Practice and Good Practice guides. Impacts of an economic, environmental and socio-cultural nature, occurring during a project's commissioning, operational and decommissioning phase, were included. The scale, probability of occurrence, duration and magnitude of these impacts were quantified wherever possible.

In addition, for each entry in the database, details of the source of information, the type of technology, its application and the sectors it is suitable for were also recorded. Using this information, the database can be searched for particular technologies or for all technologies relating to a particular sector or application. Where several sources listing different impacts for the same technology were available, all sources were entered into the database, thus enabling the user to see the range of impacts from that technology.

In order to ensure that as many impacts as possible were taken into account, and that the appropriate data was recorded for feeding into the assessment framework, the following were considered:

Project phases:

- Construction/Commissioning
- Operation
- Decommissioning

Impact types:

- Social/Cultural
- Economic
- Environmental

For each impact the following was quantified if possible:

- Impact scale (i.e. Local, Regional, or Global);
- Impact Risk (i.e. probability of occurrence);
- Impact magnitude (e.g. number of deaths, size of area destroyed);

- Length of time over which the impact will occur (i.e., during construction/decommissioning phases only, during project lifetime, exceeding project lifetime, or permanent); and
- The level of certainty of the above information.

The impacts found were checked against the list of evaluation criteria and the lists of technologies/actions, in order to identify gaps and check consistency, and the checklists were revised to take into account any gaps or inconsistencies found. Any gaps found were filled wherever possible, and checks were made for evidence that impacts exist. (It is worth noting in this context that perceived impacts, such as a decline in tourism or land prices, may also have a cost associated with them);

5.5.4 Energy Cost Calculation Tool

5.5.4.1 1990-1995

The market cost of energy consumed in each year has been calculated from the model simulation of energy demand and supply patterns for Milton Keynes using historical fuel prices for each sector (DTI, 1990-1996b). Quarterly fuel prices were used for calculating the market cost of energy consumed in the domestic, services and industrial sectors. Monthly fuel prices were used to calculate the market cost of energy consumed in the transport sector as monthly fuel prices were available. Market costs were calculated using prices paid by the final consumer including any duties and VAT payable.[9] All prices were adjusted to 1990 prices using a GDP deflator.

It was not possible to use tariff data for calculating average fuel prices for each sector as British Gas do not publish their tariffs. Also, many companies are paying much less per unit of electricity than the published electricity tariffs would suggest (Lafferty, 1997).

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9 The total paid in taxes was calculated separately. It can be argued that duties and VAT on fuels are a way of internalising some of the social and environmental costs of fuel consumption as the taxes provide Government revenue which pays for services such as the National Health Service. However, the UK tax system does not allow revenue gained from taxes to be to be set aside for a specific purpose, making the benefits gained from fuel duties difficult to calculate.

The annual energy consumption and annual energy expenditure of each of the four sectors for the baseline year of 1990 are given below, along with a description of the assumptions and methods used to calculate the annual energy expenditure for each sector.

5.5.4.2 Domestic Sector

Quarterly gas, electricity and solid fuel prices for the period 1990 to 1996, for Milton Keynes, were obtained using UK domestic fuel price indices (DTI, 1990-1996b) to adjust 1990 local prices. Local fuel prices were obtained from the *UK Digest of Energy Statistics* (DTI, 1990-1996b), which gives typical domestic fuel prices of gas, electricity and solid fuel for a selection of large towns, and for five different levels of annual household fuel consumption. Service charges are included in the fuel prices, which are based on pre-payment tariffs. Fuel prices corresponding with the mean annual household fuel consumption of Milton Keynes were used. Fuel prices for Milton Keynes were not given in the *UK Digest of Energy Statistics* (DTI, 1990-1996b). Therefore, fuel prices paid in towns served by the same distribution companies as Milton Keynes were used; it was assumed that a fuel distribution company would charge the same service charge and fuel price to all its domestic customers. Hence, electricity prices in Nottingham were used, as all both towns are served by East Midlands Electricity. Southampton gas prices were used as Milton Keynes was served by British Gas Southern; and Nottingham solid fuel prices were used. As the majority of households in the area lie within a smoke-free zone, it was assumed that most of solid fuel used in Milton Keynes for domestic heating would be a smokeless fuel (i.e. coalite).

The typical UK retail price of standard grade burning oil for 1990, given in *Energy Trends* (DTI, 1990-1996a), was used to calculate the market cost of oil consumption in domestic households.

5.5.4.3 Industrial Sector

Prices of fuel supplied to the industrial sector were taken from *Energy Trends* (DTI, 1990-1996a). It was assumed that the size mix of industry (based on fuel consumption) based in Milton Keynes was similar to that of the UK. Therefore, fuel prices based on the average prices paid by all industrial consumers were used. It was assumed that the petroleum products used for fuel purposes by the industrial sector, were a mixture of gas oil and heavy fuel oil.

5.5.4.4 Services Sector

UK fuel prices for this sector were calculated by dividing the total energy consumption of the UK services sector for each fuel type by the total expenditure by the UK services sector on each fuel type (DTI, 1990-1996b). Prices were calculated annually. No seasonal adjustments were made to prices before applying them to the quarterly supply data for the calculation market costs.

5.5.4.5 Transport Sector

Industry fuel prices were assumed for electricity and natural gas. Typical retail prices of petroleum products were taken from *Energy Trends* (DTI, 1990-1996a). A routine was added to the transport sector models to calculate the consumption of leaded and unleaded motor spirit, diesel oil and fuel oil. The assumptions used in the routine were based on figures describing the use of the different petroleum products for different modes of transport given in *Transport Statistics Great Britain* (Department of Transport, 1990-1996).

5.5.4.6 1995-2025

It was assumed that the adoption of different energy strategies in Milton Keynes would have an insignificant affect on the price paid per unit of fuel, and that fuel prices would be governed by national and international energy and pricing policies. Therefore, the same fuel prices were used to evaluate all of the energy scenarios.

5.5.4.7 Fossil Fuel Prices

Four different energy price scenarios are considered in *Energy Paper 65* (EP65) (DTI, 1995): very high, high, low, and very low. "The very high and very low energy price scenarios are designed to examine extreme energy price scenarios that could probably not be sustained in the long run" (DTI, 1995; p33). Hence, both the high and low energy price scenarios were used to calculate a probable range of market costs.[10] Prices are given as 1990 currency. The assumptions used in EP65 (DTI, 1995; p46) on the sterling/dollar exchange rate were used for calculating the monetary cost of energy consumed in each of the modelled scenarios between 1995 and 2025. Where possible the end user prices given in EP65 were used.

High and low gas prices for the domestic, services and industrial sectors were taken from EP65. Linear regression was used to extrapolate prices to 2025.

1990 and 1995 solid fuel prices paid by the domestic, services and industrial sectors were compared with prices for ARA[11] prices for steam coal. It was assumed the mark up from ARA steam coal prices to the prices paid by the consumers would be constant. (Similar assumptions were made by the DTI in EP65). The mark up for 1990 was calculated and applied to high and low solid fuel prices (DTI, 1995).

Prices paid by the domestic and services sectors for petroleum products were taken directly from EP65. For the industrial sector the price of heavy fuel oil was taken from EP65. It was assumed that light fuel oil prices would be dependent on crude oil prices. Therefore, the prices assumed for light fuel oil reflect the changes in the high and low price scenarios for crude oil given in EP65. Diesel and Motor Spirit prices for the transport sector were taken from EP65.

No prices for electricity were given in EP65. An index I_i for electricity prices was calculated using the following formula:

$$I_i = \frac{Po_iSo_i + Pg_iSg_i + Pc_iSc_i}{Po_bSo_b + Pg_bSg_b + Pc_bSc_b} * 100$$

[10] p36-38 of EP65 compares the prices assumed in the high and low energy price scenarios with energy prices assumed by other agencies. The prices assumed by other agencies are similar to the ranges used in EP65.

[11] Amsterdam, Rotterdam, Antwerp price.

Where

Po_i = the price of oil in year i,

Pg_i = the price of gas in year i,

Pc_i = the price of coal in year i;

So_i = the proportion of oil used by the electricity supply industry (ESI) to total fuel used in year i,

Sg_i = the proportion of gas used by the ESI to total fuel used in year i,

Sc_i = the proportion of coal used by the ESI to total fuel used in year i;

Po_b = the price of oil in the baseline year (1990),

Pg_b = the price of gas in the baseline year,

Pc_b = the price of coal in the baseline year;

So_b = the proportion of oil used by the ESI to total fuel used in the baseline year,

Sg_b = the proportion of gas used by the ESI to total fuel used in the baseline year,

Sc_b = the proportion of coal used by the ESI to total fuel used in the baseline year.

The proportion of fuel used by the electricity supply industry supplied by nuclear power, renewable sources and from imports varies insignificantly between the six energy-economic scenarios presented by the DTI (1995). It was assumed that the price of nuclear power would vary little as capital costs form the greatest part of the price of nuclear power generation. Therefore, nuclear power, renewables sources and imports were not included in the index.

The index was applied to the electricity prices paid by the domestic, services and industrial sectors in 1990.

5.5.4.8 Renewables

Prices for wind power were derived from figures given in Shell (1996). Regression was used to calculate prices for those years for where no data was given. The exchange rate assumptions from the DTI (1995) were used to convert prices into £ sterling.

Prices for liquid fuels (ethanol and biodiesel) were taken from ETSU (1994). For gasification of energy crops high and low prices for 1992 were calculated from information given in ETSU (1994). An estimate for prices in 2025 was taken from a graph plotting maximum practical resource against fuel prices. A linear regression was performed to obtain prices for years in-between 1992 and 2025.

The costs of electricity from solar photovoltaics (PV) are dominated by capital costs. Therefore, it was assumed that the price of a unit of electricity generated from solar PV systems would decrease at the same rate as the price of PV modules. The curve of the graph showing changes in module prices over time given in Shell (undated, p7) for 1975 to 1993 was calculated and extrapolated to give prices for 1995 to 2025. This curve was then applied to the price of electricity generated from solar PV systems in 1995 (taken from Greenpeace, 1996) to calculate prices of electricity generated from solar PV systems for 1995 to 2025.

5.5.5 The Assessment Process

The following stages were designed to ensure that the impacts that are important rather than just those impacts that can easily be quantified were considered in the evaluation of the strategies. Secondly, that there was consistency between and within the scenario evaluations.

For each strategy to be assessed, a scenario[12] was generated and entered into the energy model. A series of assumptions were made about how the strategy would be implemented and how each sector within it would be implemented (these are documented in Chapter Six). The model was used to calculate consumption of fossil

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[12] A series of scenarios could just as easily be generated for each strategy, representing for example different economic conditions.

fuels and greenhouse gas emissions. Energy consumption figures from the model were fed into the monetary cost evaluation spreadsheet before being entered into the assessment framework.

A list of the technologies used in each scenario was then compiled, based on the assumptions made for the modelling work. For each technology the impacts were extracted from the impacts database.

For each of the impacts in the scenario being considered, the costs and benefits were evaluated. If costs could not be quantified, but impacts or burdens were available, these were listed alongside qualitative information on costs/benefits. Capital costs were quantified using a range of possible future prices at a discount rate of 5%.

Technologies with similar impact types were then grouped together for each scenario. Those impacts that were quantified were summed. Where it was not clear that impacts could simply be summed, due to possible synergistic and nulling effects, the data was presented in a qualitative rather than quantitative format. Some impacts were converted to the same unit to aid comparison - for example, the global warming potential of various different gaseous emissions were expressed in terms of their carbon dioxide equivalent. This grouping and summarising process was repeated several times until the initial impacts data was collapsed into the assessment framework outlined above.

MILTON KEYNES ENERGY STRATEGIES

6.1 Overview of the Strategies

The methodology outlined in Chapter Four was tested by applying it to a series of energy strategies for Milton Keynes. These strategies were developed to reflect the level of greenhouse gas emission reductions and energy consumption reductions that were considered possible to achieve for Milton Keynes and to demonstrate the variety of ways in which reductions could be achieved.

6.1.1 Current Trends Continued (1995 base) (CTC95)

In this strategy it is assumed that no additional effort over and above current practices is made to reduce the emissions due to the burning of fossil fuels. Established social trends continue, such as the demand for higher levels of comfort, the number of labour saving devices in operation and the temperature to which rooms are heated.

6.1.2 Fuel Switching (FSW)

The Fuel Switching (FS) Strategy, assumes that consumers would be encouraged to switch to less carbon-intensive energy sources and to sources producing less local pollution. Apart from the efficiency improvements usually associated with the purchase of new equipment, no additional energy efficiency improvements (other than those that would have been implemented in a Current Trends Continued strategy) are assumed.

6.1.3 Technical Fix (TFX)

In this strategy, every effort is made to reduce GHG emissions, for example through the use of technologies to improve the efficiency of the energy conversion processes (e.g. improved boiler efficiencies); and through the use of technologies to reduce the demand for energy (e.g. wall insulation). However, a stipulation of this strategy was that the technologies must be *economically viable* in order to be implemented. ('Economically viable' technologies were defined for the purposes of this project as those in which the savings produced repay their capital costs in less than 5 years, i.e. they have a simple payback time of 5 years) In this strategy, it was assumed that people's lifestyles and expectations would not change substantially.

6.1.4 Local Agenda 21 (LA21)

The Local Agenda 21 (LA21) strategy assumes that the city adopts policies consistent with the Agenda 21 process initiated at the United Nations' 1992 Earth Summit in Rio de Janeiro, as laid out in Milton Keynes' local agenda 21 document (MK21 Steering Group, 1997). Policies and targets not directly concerned with energy but strongly related to energy consumption, such as the policy to improve local air quality through greater use of electric vehicles, are included.

6.1.5 Green (GRN)

In this strategy all the proposals in the technical fix strategy are implemented. In addition technologies which are available at the present time but are not currently considered economically viable (due to long payback times) are also put into action. It is assumed that people change their lifestyles substantially, choosing options which will have least environmental consequences wherever possible, for example wearing warmer clothing in the winter and using public transport where possible.

6.2 Assumptions Underlying the Scenarios

For each of the strategies a single scenario was developed. This involved making numerous detailed assumptions about the likely future values of model parameters. The assumptions made for each of the scenarios are outlined below. All the scenarios assumed a base year of 1995 and that the strategy would be in place until 2025. These scenarios were developed in 1996/7 and are thus based on the trends apparent, information available and policies in place at that time. A series of tables comparing the assumptions for each scenario are given in the Annex to this chapter.

6.2.1 Current Trends Continued (1995 base) (CTC95)

This scenario forms the basis for all of the other options. As the name of the scenario suggests the basic premise behind the scenario is that current trends in population growth, manufacturing and service sector growth, traffic growth, energy efficiency improvements and fuel choices continue for the next 30 years. Official statistics and government projections have been used where possible. Where not, academic and technical literature has been drawn upon extensively to gain an overview of what changes are likely to occur. For those very few of the model parameters on which no future trend information could be found from either government, academic or commercial sources, a crude extrapolation of previous trends was used. In order to show the variation likely due to changes in the weather, data on mean monthly external temperature for approximately a 10 year period was repeated to generate variation for 1995 onwards. The effects of long-term climate change were not taken into account.

6.2.1.1 Energy Supply

Government projections for fuel mix for electricity generation were used based on central projections of economic growth and taking an average of the high and low fuel price scenarios from Energy paper 65 (Dti, 1995a). These figures suggest that renewables will be supplying just less than 1% of primary energy demand by 2020, but no details are given as to how the assumed renewables generating capacity of 5GW is met. It was assumed that this would be achieved through large-scale schemes feeding the national grid. Renewable energy schemes within the boundaries of the Milton Keynes Council area were assumed to be in addition to this 1%, although in the current trends continued strategy the level of renewables installed within the Council area was assumed to be negligible.

It is worth briefly explaining how CHP is treated within the DREAM model. On the supply-side the user is required to enter the kWe of plant that is installed in the model area and the typical ratio of heat to electricity produced by that plant. The model then calculates expected output from the system. In a separate section of the model the fuel used to power the CHP plant is determined based on thermal output and plant efficiency. On the demand-side, fuel demand is determined by allocating a percentage of total demand to each of five 'fuel' types – electricity, gas, oil, solid fuel and heat, where heat is the thermal demand supplied by CHP (or district heating) based schemes. It is assumed that CHP plant installed is sized to meet at maximum the base load of the heat demand, with the peak (or remaining) thermal load being met by conventional boilers. In calculating the system efficiency of the CHP system, a thermal efficiency is used with the assumption that the electricity is a bonus.

6.2.1.2 Services Sector

Information on the total number of square metres of floor area of buildings for the period 1980 to 1995 in each services sub-sector came from a variety of different sources including: Milton Keynes Borough Council, the Commission for New Towns, Buckinghamshire County Council, Milton Keynes NHS Trust, and the Open University. Where data was only available on the number of buildings used for a particular purpose, a figure for total floor area was estimated using data on the typical floor area of buildings used for that sector. Table 6A.1 in the annex to this chapter gives the floorspace figures used for each sub-sector for 1995, together with estimates for 2010 and 2025. A fairly conservative estimate of floor space growth between 1995 and 2025 was used, with floor space assumed to grow by 30 percent over the 30 year period, at a rate of slightly under 1% per annum. This rise is similar to that used in the Leicester Energy Model (Boyle *et al*, 1994) for the Business As Usual Scenario. It was felt that Milton Keynes was nearing completion and that future growth was likely to reflect growth of other UK cities rather than continue at its current higher rate.

Historical data on the mean "heat loss parameter" (i.e. heat loss in watts per square metre of floor area for each degree Celsius difference between internal and external temperature, i.e. $Wm^{-2}C^{-1}$) for buildings in each sub-sector was derived from regression analysis using data from Herring *et al* (1988). Between 1995 and 2025, the heat loss parameter for the majority of the sub-sectors was assumed to decrease by 25% (see Table 6A.2) in line with the assumptions made by Boyle *et al* (1994) for their Business As Usual Scenario. The heat loss parameters for the personal services and commercial services sub-sectors were assumed to decrease by 13%, due to the already low heat loss parameter for these sub-sectors, and, therefore, lower potential for energy savings.

The mean internal temperature of service sector buildings was estimated to be 17°C in 1995. Historically, mean internal temperatures of buildings have been rising due to increased occupation times and increasing standards of comfort (Herring *et al*, 1988). The mean monthly internal temperature for all sub-sectors was thus assumed to rise to 18°C by 2025 (Table 6A.3). This was felt to be approaching saturation level, so larger rises in mean internal temperature would be unlikely. Historic data on mean monthly external air temperatures for the region were provided by The Meteorological Office from the weather station at Woburn (GR 4964E 2360N, 89m AMSL).

Data on the efficiency of conversion from delivered to useful energy in each sub-sector for each of the energy sources; the share of annual delivered energy provided by each of the energy sources; and annual mean useful energy supplied for lighting, water heating, cooking and other uses per square metre of building floor area were taken from Herring *et al* (1988).

Demand for delivered energy for cooking and water heating was assumed to decrease over time, through the increased use of lagging on pipes and tanks, together with better controls, at a rate of just under 1% per annum. The energy consumption of appliances used to supply this demand was assumed to increase by 25% by 2025, due to the increasing use of electrical equipment such as computers.

The efficiencies of all space heating appliances were assumed to increase over the period by up to 35% compared with 1995 levels, depending on the type of appliance and fuel used, continuing current trends (Boyle *et al*, 1994). Water heating efficiencies in general were assumed to be lower than space heating efficiencies due to heat loss through tank storage and pipes. Efficiencies of cooking appliances burning oil, solid fuel or gas were assumed to increase from an average of 11% in 1995 to 15% in 2025 (see the Business As Usual Scenario developed by Boyle *et al*, *op. cit.*). Electric cooking appliances were assumed to increase from a mean efficiency of 20% to 25% over the same period, again in line with assumptions made by Boyle *et al* (*op. cit.*). Greater efficiency increases were assumed for gas water heating and space heating systems than for oil and solid fuel systems, as it was assumed that the majority of new buildings would be constructed with gas systems rather than oil or solid fuel systems thus the uptake of the latest improvements would be faster with gas systems. Table 6A.4 gives the efficiencies used for 1995 and 2025 for each type of system.

The specific power (i.e. the demand per unit of floor area in Wm^{-2}) used for lighting was assumed to decrease by 30%, over the period 1995-2025 (Table 6A.5). The specific power used for other purposes, such as electrical equipment and refrigeration, was assumed to increase over time, reaching up to 125% of 1995 levels by 2025 (Table 6A.6). This increase was assumed to occur, despite better appliance efficiencies, as a result of a greatly increased demand for such equipment.

The use of electricity to provide space heating was assumed to continue to increase, a reflection of the increasing use of air conditioning in both public and commercial buildings. The only other fuel to increase its share of this market was heat from CHP plant, which was assumed to increase from 1% to 2% of total energy demand by 2025, except in the health sub-sector, which had a much higher level of CHP usage in 1995, where it was assumed that an increase to a 40% share would occur. The use of solid fuel, oil and gas for space heating was assumed to decrease for all sub-sectors. Similar trends were assumed for water heating; the main difference being an increase in the use of electricity to supply water-heating demand due to firms switching to "instant" water heaters to provide hot water needs. The use of solid fuel and oil for cooking, already negligible in 1995, was assumed to continue to decrease. Electricity use for cooking was assumed to increase with an increased use of electrical appliances such as microwaves. Use of gas for cooking was assumed to decrease slightly (see Table 6A.7(a)).

Street lighting in the model is divided into 3 different types based on control patterns – no control, timer-controlled, and those controlled by photocell. The total wattage of those with no control is entered and simply multiplied by the number of hours in the month to give total electricity demand for this type of lighting. For those with photocell control, the total wattage is multiplied by the number of hours of darkness. Lights with timer controls are treated slightly differently. In this case the number of Kilowatt-hours is input into the model, which allows a large number of different timer settings to be taken into account. Milton Keynes Council provided the required data on street lighting. Based on the Business As Usual Scenario in Boyle *et al* (1994), it was assumed that savings through use of better controls and more efficient light bulbs would off set the increase in the length of streets being lit, resulting in zero net growth.

6.2.1.3 Domestic Sector

Population

The number of residents in the Council Area was taken from the Census of Population for 1981 and 1991. Mid-year estimates were used for the intermediate years (OPCS, 1993). Government population projections for the unitary authority (1991-2011) (Buckinghamshire County Council, 1994a) were entered and the resulting curve extrapolated to 2025 (see Figure 6.1 and Table 6A.12).

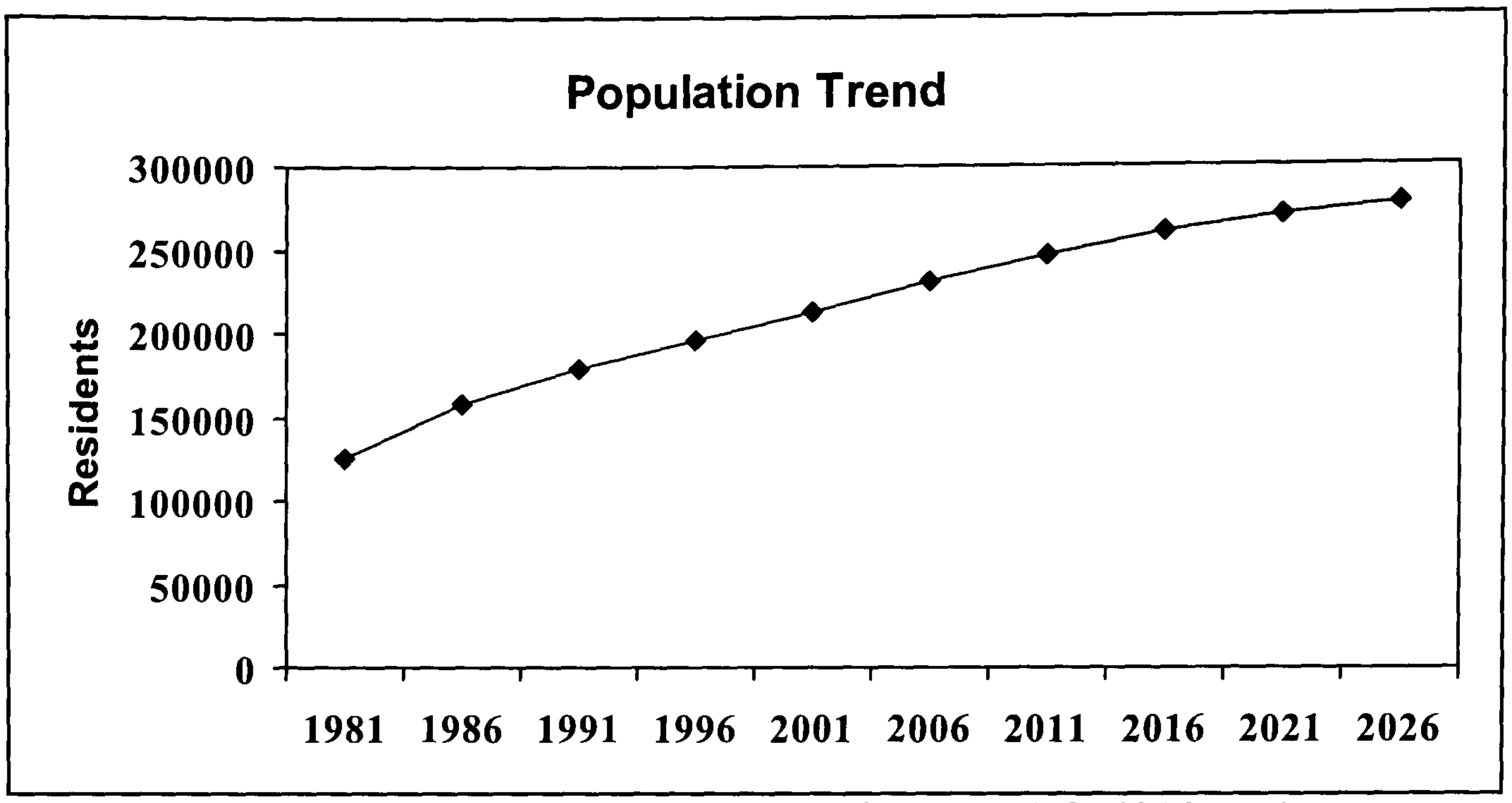

Figure 6.1: Milton Keynes Population Trend 1980-2025, CTC95 Scenario

The transient population (the residents spending part of their year in Milton Keynes, for example, students) was assumed to decrease over time. In 1995, it was estimated that approximately 2000 students were resident in Milton Keynes (De Montfort University registrars office, 1995). It was assumed that the student population would continue to increase in line with the University expansion programme of recent years, doubling by 2025.

Household Size

The number of people per household in Milton Keynes was 2.88 in 1980, falling to 2.54 by 1995 (Based on OPCS, 1984, 1993; MKBC, 1994). This trend was assumed to continue, resulting in a decrease to 2.28 people per household by 2025, based on DoE (1995) projections of household size which suggest nationally a reduction of 0.25 persons per household over a 25 year period (Figure 6.2 and Table 6A.12).

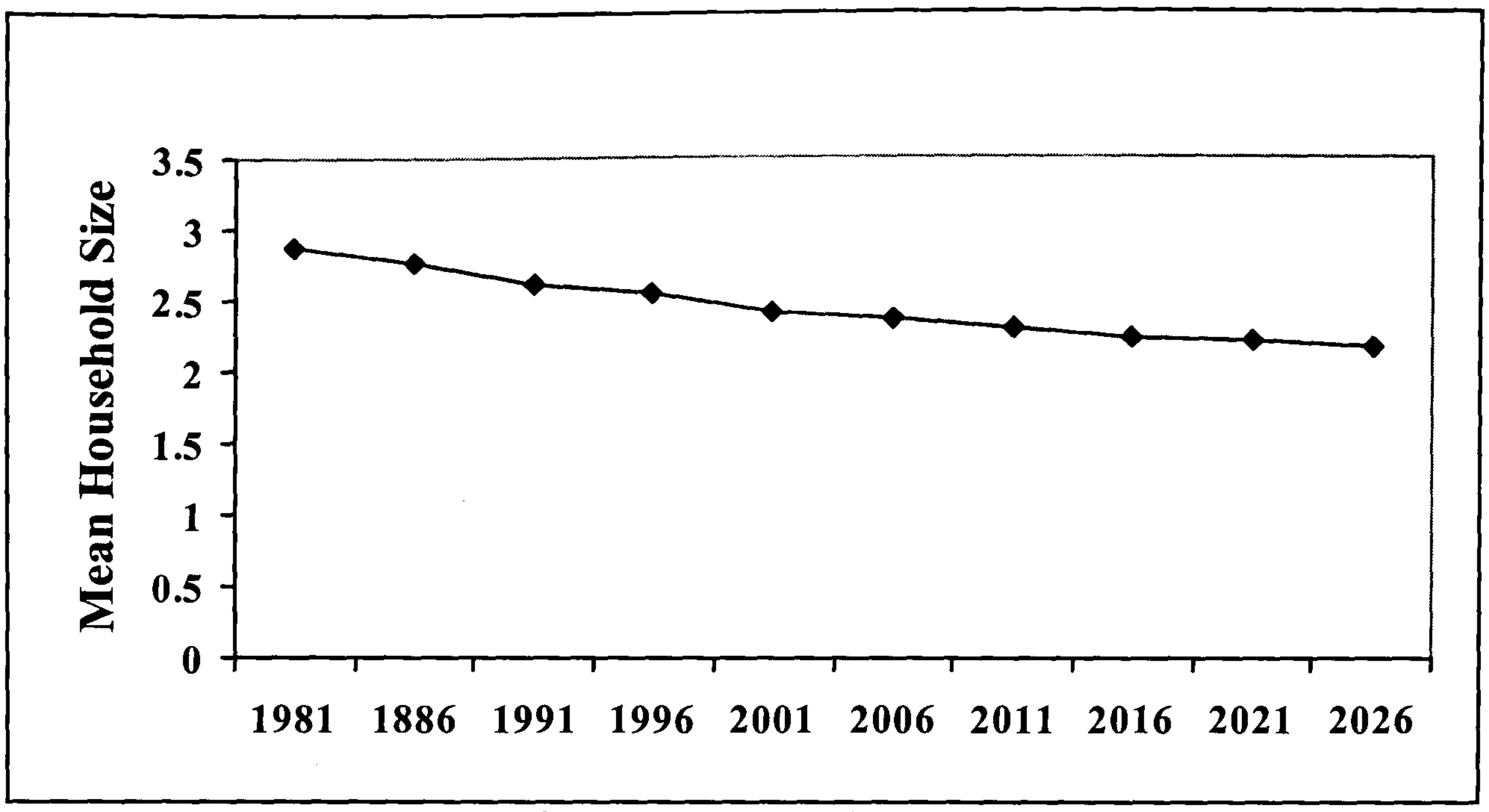

Figure 6.2: Milton Keynes Household Size 1980-2025

Dwelling Characteristics

The average floor area of dwellings was estimated to be 90m^2 in 1980, based on the housing mix within the Council area. The Building Research Establishment (BRE) provided data on the national mean floor area (m^2) for different dwelling types (BRE, 1994). The mix of dwelling types in Milton Keynes was obtained from the 1991 Census of Population (OPCS, 1993). The mean floor area of all dwellings was calculated using the BRE data and the 1991 mix of dwelling types in Milton Keynes. This figure was then compared with the figure provided in the Local Housing Statistics. For simplicity, it was assumed that one household only occupied each dwelling. The Commission for New Towns and Milton Keynes Council provided the annual rates of building of new households and DoE/DETR Local Housing Statistics provided data on demolition rates, and numbers of dwellings converted to non-domestic use. These were used to estimate the changing mix of housing types within Milton Keynes Council area and thus changing floor area. It was then assumed that dwelling floor area would decrease to 84m^2 by 2025, similar to national trends (BRE, 1994).

The model uses the mean heat loss parameter (i.e. heat loss in watts per degree centigrade difference between external and internal temperatures per square metre of floor area) for the region's housing stock (i.e. all public and private houses) to calculate the space-heating requirement. The calculation of the average heat loss parameter was done in a spreadsheet specially created for the purpose and based on BREDEM

(Anderson *et al*, 1985a: 1985b). Using the Local Housing Statistics for England and Wales 1970 to 1984 (DoE, 1992), Housing Development Report 1993/94 (MKBC, 1995), BCC Structure Plan data (Buckinghamshire County Council, 1994b), a list of the number of houses constructed in each year between 1970 and 1995, and those constructed before 1970, was made. These were then grouped into pre 1975, 1975-81, 1982-87, 1988-1997 and 1997 onwards. The first three groupings were based upon dates of new Building Regulations. The final two groups consisted of dwellings built after the Commission for New Towns adopted an NHER standard of 7.5 and 8.0 respectively for all new dwellings built on commission land. This covers the majority of dwellings built since 1988 in the Milton Keynes Council Area. It was assumed that the mix of different dwelling types did not change significantly between the four age groups. Using information from a variety of sources, (including: the English House Condition Survey (DoE, 1988, 1991, 1993, 1996) and Anderson *et al*, 1985a: 1985b), a profile of construction types, levels of insulation, and u-values was built up for each type and age of dwelling. These were then entered into a spreadsheet based on BREDEM (version 9.1) (Anderson, 1988) and a mean heat loss parameter for all dwellings was calculated for 1981, 1994 and 1995.

It was assumed that by 2025 all dwellings within the Council Area would have double-glazing, and some level of draught-proofing and loft insulation in line with assumption made by Boyle *et al* (1994) in their Business As Usual Scenario. Additionally, 50% of the modern housing would have cavity-wall insulation, whilst the pre-war terraced housing and converted flats were assumed to still have no wall insulation. The majority of purpose-built flats were expected to have either external wall insulation, installed as part of refurbishment schemes, or cavity wall insulation, depending on their structure. These assumptions were entered into the heat loss parameter spreadsheet along side assumptions on the future level of construction of new dwellings to calculate a heat loss parameter for 2025. In terms of future dwelling construction, it was assumed that the mix of dwelling types being constructed would remain unchanged and that construction rates would meet demand, based on one dwelling per household and the trends in population growth and household size outlined above. The values for 1981, 1995 and 2025 were interpolated to produce mean heat loss parameter values for all other years modelled. These values are shown in Figure 6.3 (see also Table 6A.13).

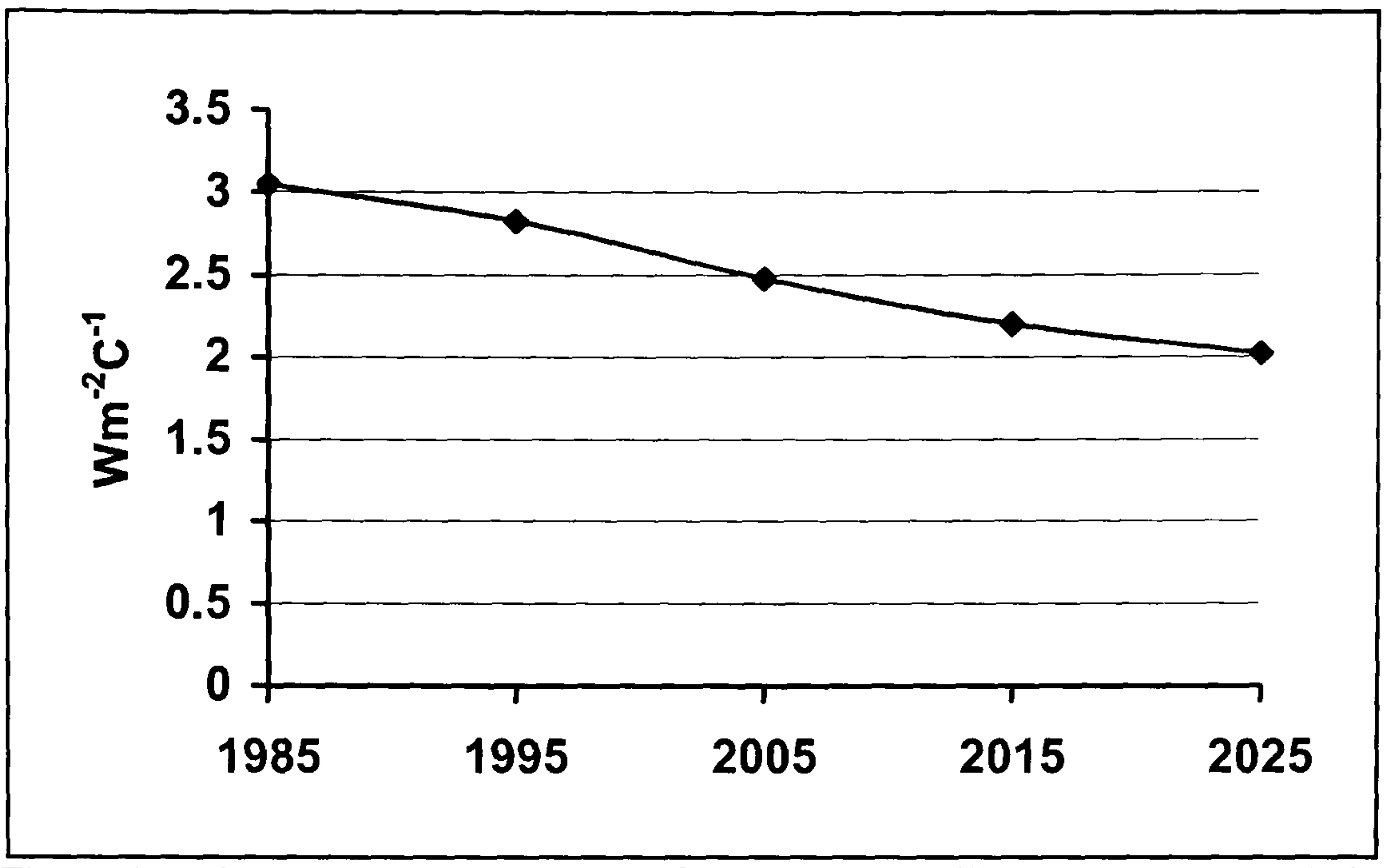

Figure 6.3: Mean Heat Loss Parameter for Housing in Milton Keynes, 1985-2025

Initial assumptions on the mean monthly whole house internal temperature for the area's housing stock were based on Leicester City Council's estimate for its Council Housing Stock and data from the English Housing Condition Survey 1991 Energy Supplement (DoE, 1996). No data was available for Milton Keynes. The required mean monthly internal temperature was assumed to continue rising, in line with past trends, reaching 18°C in 2025 (Figure 6.4 and Table 6A.14). This figure includes periods when the dwellings are not being heated (i.e during the middle of the day and over night).

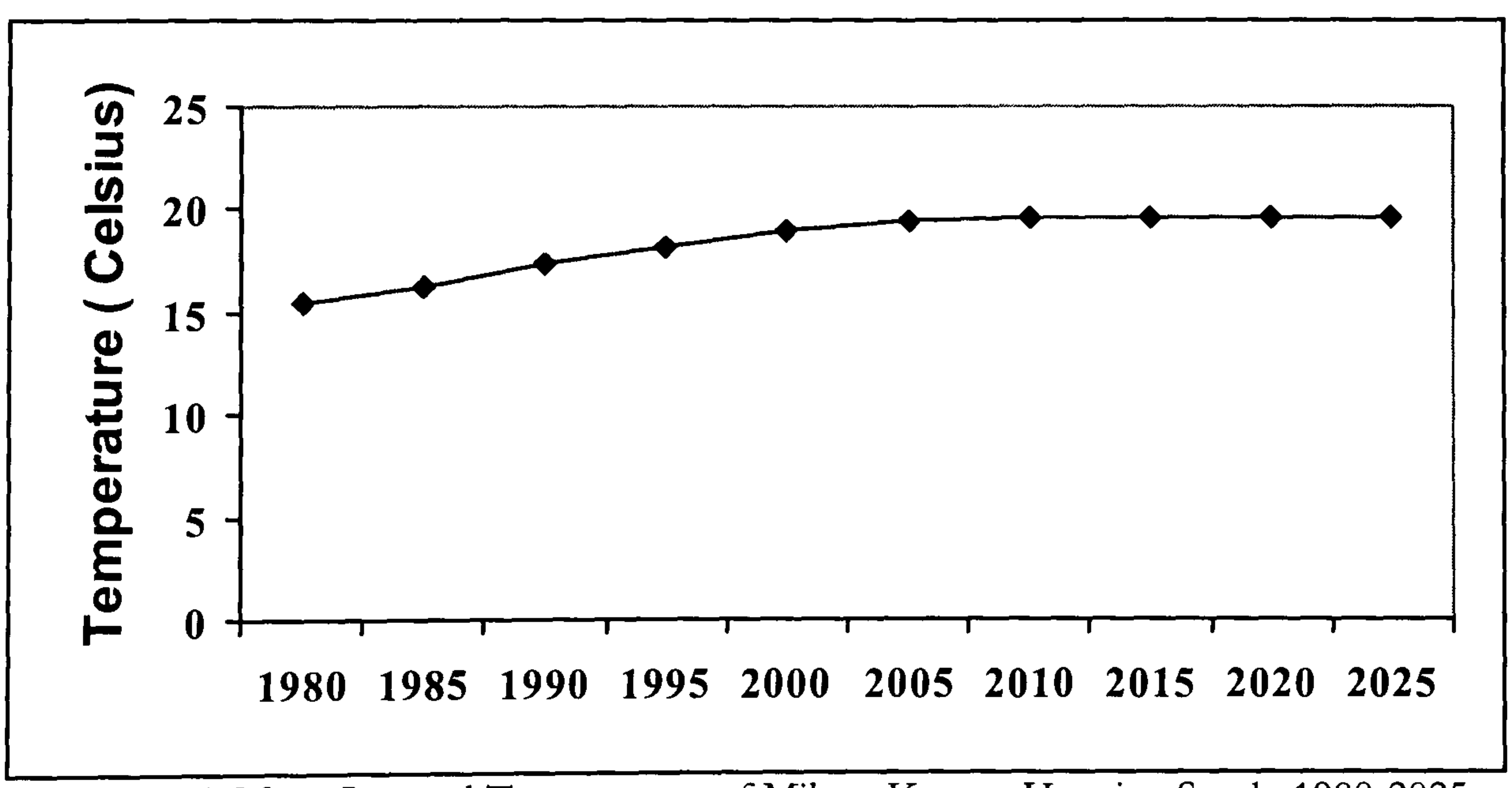

Figure 6.4: Mean Internal Temperature of Milton Keynes Housing Stock, 1980-2025

End-Use Services

Figures used in the model for the shares of domestic space heating energy supplied by gas, electricity; solid fuel, CHP/DH (Combined Heat and Power and/or District Heating), oil and renewables between 1980 and 1995 were based on information from a variety of sources including: British Gas and East Midlands Electricity, Dept. of Environment (1991), Herring (1995) and, Evans and Herring (1989). Similar sources were used to provide figures for the shares of domestic water heating and cooking energy supplied by each of the above energy sources.

Between 1995 and 2025, a small increase in the use of electricity for cooking and water heating was assumed, due to the greater use of washing machines, electrically heated showers, halogen hobs in cookers, etc., reducing some of the market share held by gas in 1990. The energy demand for all end-uses supplied by solid fuel and oil were assumed to remain unchanged; they are already very small. The demand for heat from district heating schemes was set to rise only slightly, as it was assumed that the low-density nature of Milton Keynes was likely to place the cost of installation of such schemes above the level at which developers were prepared to invest in them (Table 6A.15).

It was assumed that there would be no change in the level of cooking demand (measured as mean monthly useful cooking demand – i.e. the heat actually required to cook the food, not including the efficiency of the cooking appliance or any heat lost to the atmosphere). It was also assumed that the seasonal variation of this demand would not change over time.

The number of households with solar water heating systems installed was assumed to rise from approximately 50 in 1995 (see Section 3.2), making up 0.08% of the housing stock, to 1.6% of the total housing stock by 2025 (Table 6A.16). Monthly solar radiation data (MJ per sq. metre on horizontal surface) was for latitude 52°37'N. The relatively high cost of installing such systems and poor payback rates were thought likely to prevent any large scale uptake of this technology. The model assumes that the solar water heaters act as pre-heaters, with conventional systems providing the top up heating to get the water to the required temperature.

The temperature of the water at the tap was assumed to remain at 1995 levels. Consumption of hot water is broken by the model into two elements: a base level of consumption per household irrespective of the number of people within the household, and an additional amount consumed per person in the household. The figures of 38.5 litres a day per household and 24 litres a day per person in 1984, used in the model were based on the BRE formula for calculating daily hot water demand per household (Anderson *et al*, 1985a). It was assumed that this consumption would increase over time, due to increased use of dishwashers, power showers (as opposed to ordinary showers) and garden hoses – rising with rising living standards to 57 litres and 36 litres per household and per person respectively by 2025, i.e. to 50% above 1995 levels by 2025 (Table 6A.17). This assumption is also in line with the assumption made by Boyle *et al* (1994) for their Business As Usual Scenario.

It was assumed that the demand for energy for lighting and appliances per household would increase at a rate similar to the current rate of around 3.5% per annum, reaching a mean level of approximately 420W per household by 2025 (see Figure 6.5 and Table 6A.18). Efficiencies for the conversion of the different energy sources to useful energy for each end-use service (such as space heating) were based on figures in Herring and Evans (1989) (Table 6A.19).

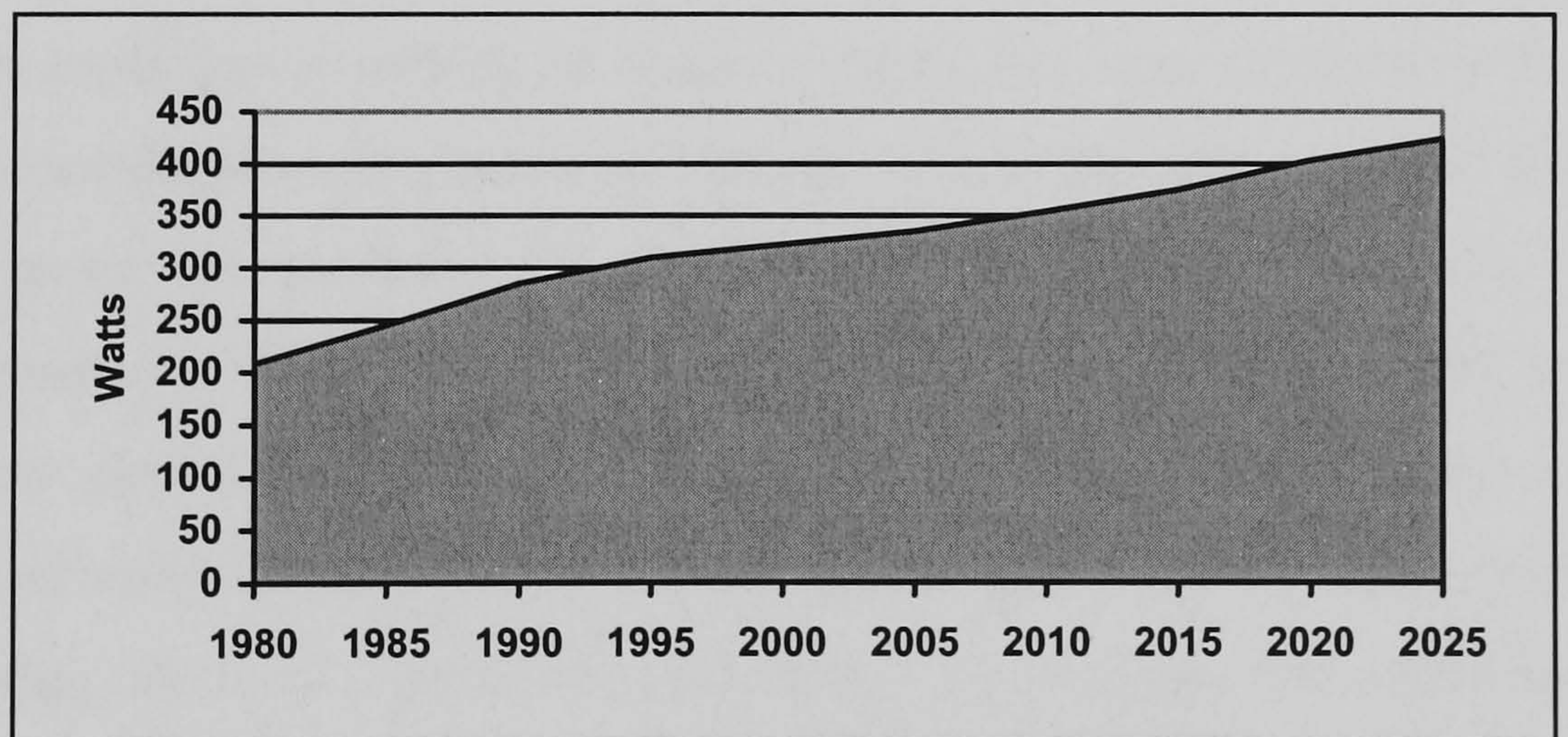

Figure 6.5: Lighting and Appliance Demand per Household 1980-2025

6.2.1.4 Industrial Sector

The Business Statistics Office of the Central Statistics Office provided data on the monetary value of annual output from each Standard Industrial Classification (SIC) category (2 figure classes) for 1981 and 1992. From this an output per unit of time

(£/sec) value was calculated. It was assumed that the changes between these years were linear and that production continued to increase at the same rate until 1995. Seasonal variations in production were not included.

Data on non-domestic floor area by 4 figure Standard Industrial Classification (SIC) codes was provided by MKBC for 1994. Each entry in the database also included a Town and Country planning use class. This enabled office, retail and warehousing floor space to be separated from industrial (manufacturing and assembly) floor space. A floor space total was calculated for each of the industrial sub-sectors in the model. The Commission for New Towns provided information on commercial floor space for 1980 to 1995. This data was broken down into three categories: Industrial, Offices and Shopping. It was assumed that floorspace in each of the industrial sub-sectors increased at the same rate as the number of units[13] between 1981 and 1995.

The mean 'heat loss parameter' ($Wm^{-2}C^{-1}$) figures for buildings within each sub-sector were derived from national figures using regression analysis, see Boyle (1996).

No information was available on the mean internal temperature of buildings within each SIC category, it was, therefore, assumed that the mean internal temperature of industrial buildings did not differ greatly from that of domestic buildings.

The energy input per £ sterling of output (termed the 'specific power') for each sub-sector was calculated using data from Schaffer (1989) and data provided by ETSU on industrial sector energy demand. Data on UK industrial output was taken from Business Monitor PA1002 (CSO, 1995) and outputs were adjusted to 1980 prices. Both sets of data gave energy demand for various different energy sources by 4 figure Standard Industrial Classification (SIC) categories. For each SIC category the national average energy input per £ output was calculated. These figures were then weighted and summed to give a figure for the energy input per £ output for each sub-sector. The weighting for each SIC category was calculated by dividing the local industrial floor area

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13 This is the term used by the Central Statistics Office, in the Annual Census of Production, for each manufacturing plant or site located in the area.

in each 4 figure SIC category by the total industrial floor area in each sub-sector. The share of annual delivered energy provided to each SIC category by each of the different fuel types was calculated in a similar way.

1980 to 1995 data for the annual index of prices of industrial products was taken from the Annual Abstract of Statistics (CSO, 1980-1997). A base of 100 in 1980 was used. Where 2 figure SIC classes needed to be amalgamated to fit the sub-sectors used in the model, the classes were weighted, using output of production data for Milton Keynes, and then summed.

For the years 1995-2025, different assumptions were made for each of the industrial sub-sectors; these assumptions were based on the national growth rates used in Energy Paper 65 (Dti, 1995) with some adjustment to reflect the historic trends of the individual sub-sectors within the Milton Keynes Council Area. The rate of change historically of output per square metre was calculated for each sub-sector and floor area growth rates were based on the assumption that these increases in productivity per square metre would continue. The heat loss parameter for all sectors was assumed to decrease from 3.5 $Wm^{-2}C^{-1}$ in 1995 to 2.8 $Wm^{-2}C^{-1}$ in 2025, a reduction of 21% (Table 6A.25).

Ceramics

The ceramics sub-sector has not expanded in Milton Keynes significantly over the last 15 years. Nationally it is expected to grow by just under 1% per annum (Table 6A.26). Therefore, it was assumed that this sector would increase its output by slightly under this amount at 0.8% per annum, but that there would be no increase in floorspace (Table 6A.27). Historically, the specific power of the ceramics sector has wavered considerably within its overall downward trend. It was assumed that this downward trend would continue, with a reduction in energy required per unit output of approximately 30% between 1995 and 2025 (Table 6A.28). It was expected that this sector would undergo only relatively small changes in demand for different fuels. It was assumed that the use of CHP plant would increase from supplying 6% of energy demand in 1995 to 8% in 2010, reaching 11% by 2025 (Table 6A.29(a)). This rate of increase was assumed to be slightly less than the historical rate of increase on the basis that those sites with the highest potential rates of return would be the first to install

CHP. The use of oil was assumed to continue to diminish from 2% in 1995 to negligible amounts by 2025. The level of solid fuel use in this sector was already negligible in 1995 and it was assumed that this would not change. The demand for electricity was expected to stay fairly constant, supplying around 13% of demand, whilst demand for gas for non-CHP systems was assumed to decrease slightly from 78% of total demand in 1995 to 76% in 2025.

Construction

In the construction industry there is little potential for CHP due to the mobile nature of the industry, therefore it was assumed that CHP would continue to be insignificant (Table 6A.29(a)). It was assumed that oil and solid fuel would decrease from 17% and 2% respectively in 1995, but that oil would continue to supply site generators, resulting in a market share of 10% for oil and 0% for solid fuels. Electricity usage was also assumed to increase, particularly for space heating of storage areas, from 33% to 41% in 2025; whilst gas demand would remain steady at just under 50% of total demand. It was assumed that the construction industry within Milton Keynes would not increase substantially in size (floorspace) (Table 6A.27), although output was expected to increase by 50% between 1995 and 2025 in line with national growth rates (Table 6A.26). The rate of decrease in the power required to produce a unit of output (i.e. the specific power) in this sector was assumed to slacken off slightly from historical trends, achieving savings per unit of production of 17% in 2025 compared with 1995 (Table 6A.28).

Chemicals

For the chemicals sub-sector it was assumed that floor area continues to increase from 53,000m^2 in 1995 to 69,000m^2 in 2025 (Table 6A.27), at a slightly slower rate (approximately 1% per annum) than the historic trend as the city reaches its planned capacity. Output from this sector was assumed to increase at the same rate as the national average of approximately 2% per annum (Table 6A.26). The rate of decrease of the energy used to produce a unit of output was assumed to tail off significantly, as it was felt that the dramatic improvements in energy efficiency achieved over recent years could not be sustained and indeed was already showing signs of tailing off (Table 6A.28). It was assumed that the use of CHP would continue to become more popular in this sector as would the use of electricity and gas, increasing from 10%, 26% and 47% in 1995 to 15%, 30% and 52% in 2025 respectively. The use of oil, already in small demand in 1995 (0.9%) was assumed to drop to virtually nothing by 2025, whilst the use of solid fuels for energy was assumed to drop to substantially from 16% of total demand of the Chemicals sector in 1995 to just 3% in 2025, as tougher legislation on emissions comes into play (Table 6A.29(a)).

Engineering

Although the engineering sub-sector is rapidly expanding at present, it was assumed that this will not continue and that the sub-sector will continue to develop at a rate similar to other sub-sectors (2.3% per annum) (Table 6A.26). In terms of floorspace the sector was assumed to grow at a rate of 1% per annum until 2010 and then 0.3% per annum thereafter, reflecting the decreasing rate of growth of floorspace in this sector seen over the past 20 years Table 6A.26 The specific power for this sector was assumed to continue to decrease at a steady rate, achieving a 22% saving per unit of output from 1995 levels (Table 6A.28). Use of CHP was assumed to increase substantially, from supplying, in terms of thermal output, 24% of total demand in 1995 to supplying 36% of demand. It was assumed that gas use would decrease from 43% in 1995 to 26% in 2025, with companies switching away from conventional systems towards CHP. However, electricity demand was assumed to continue to increase as the sector moved away from heavy engineering to towards high-tech industries, rising by 5% from 1995 to reach 38% in 2025 (Table 6A.29(a)). Oil and Solid Fuel use in this sector was already negligible and it was assumed that this would not change.

Food, Drink and Tobacco

For the Food, Drink and Tobacco sub-sector it was assumed that floor area continues to increase from 33,000m^2 in 1995 to just under 40,000m^2 in 2025 (Table 6A.27), but at an increasingly slower rate (just under 1% per annum) than the historic trend as the city reaches its planned capacity. Output from this sector was assumed to increase at the same rate as the national average of approximately 1.3% per annum (Table 6A.26). The rate of decrease of the energy used to produce a unit of output was assumed to tail off significantly, similar to the Chemicals sector, as again it was felt that the dramatic improvements in energy efficiency achieved over recent years would not be sustained

(Table 6A.28). It was assumed that the use of CHP would continue to become more popular in this sector as would the use of electricity and gas, increasing from 4%, 26% and 62% in 1995 to 8%, 28% and 64% in 2025 respectively. The use of oil, 8% of demand in 1995, was assumed to drop to virtually nothing by 2025, whilst the use of solid fuels for energy was assumed to remain at negligible levels (Table 6A.29(a)).

Manufacturing Vehicles and Vehicle Parts

The manufacturing vehicles and vehicles parts industry was assumed to increase its output at a rate similar to historical trends (0.5% per annum) (Table 6A.26), whilst growth in floor area was assumed to increase at a decreasing rate, reaching 32,000m2 in 2010 and then only 35,000 by 2025 from a starting point of 28,000m2 in 1995 (Table 6A.27). Historically, the specific power of this sector has been decreasing and this was assumed to continue but at a slower rate (Table 6A.28). The use of gas was assumed to remain steady at 41% after 1995, as industry switches away from conventional gas boilers to CHP systems. Similarly, use of oil was assumed to decrease from 17% to 6% over the next 30 years. The demand for heat from CHP systems was assumed to rise from 18% in 1995 to just under 25% in 2025 (Table 6A.29(a)).

Metals

The metals sub-sector was assumed to grow by just over 1% per annum (Table 6A.26), similar to national rates. Allowing for an increasing rate of output per unit of floor area, it was assumed that floorspace would increase from 81,000m^2 in 1995, to approximately 87,000m^2 in 2010 and 90,000m^2 in 2025; a rise of approximately 10% (Table 6A.27). Historically, the specific power of the metals sector increased during the late 1980s, and although it has returned to a downward trend, is still at a level above that reached in the early 1980s. It was assumed that the overall downward trend would continue, with a reduction in energy required per unit output of approximately 15% between 1995 and 2025 (Table 6A.28). It was expected that this sector would undergo only relatively small changes in demand for different fuels. It was assumed that the use of CHP plant would increase from supplying 10% of energy demand in 1995, reaching 15% by 2025. The use of oil was assumed to continue to diminish from less than 1% in 1995 to negligible amounts by 2025. The level of solid fuel use in this sector was already negligible in 1995 and it was assumed that this would not change (Table 6A.29(a)). The demand for electricity was expected to stay fairly constant, wavering around supplying 20% of demand, whilst demand for gas for non-CHP systems was assumed to decrease slightly from 70% of total demand in 1995 to 65% in 2025.

Miscellaneous

For the miscellaneous (other) sub-sector it was assumed that floor area continues to increase from 27,000m^2 in 1995 to 28,000 in 2010 and to 30,000m^2 by 2025, at a slightly higher rate (approximately 0.3% per annum) than the historic trend as manufacturing diversifies away from the more traditional sectors (Table 6A.27). Output from this sector was assumed to increase at the same rate as the national average of approximately 2% per annum (Table 6A.26). The rate of decrease of the energy used to produce a unit of output was assumed to tail off significantly, as it was felt that the dramatic improvements in energy efficiency achieved over recent years could not be sustained and indeed was already showing signs of tailing off, resulting in a reduction in the energy consumed per unit of output of 16% between 1995 and 2025 (Table 6A.28). It was assumed that the use of CHP would continue to become more popular in this sector as would the use of electricity and gas, increasing from 8%, 38% and 37% in 1995 to 10%, 45% and 39% in 2025 respectively (Table 6A.29(a)). The use of oil (17% in 1995) was assumed to drop drastically to 6% by 2025, whilst the use of solid fuels for energy was assumed to continue to be negligible.

Paper and Printing

The paper and printing industry sub-sector was assumed to increase its output at a rate similar to national rates (2% per annum) (Table 6A.26), whilst growth in floor area was assumed to increase at a decreasing rate, reaching 45,000m2 in 2010 and then only 50,000 by 2025 from a starting point of 38,000m2 in 1995 (Table 6A.27). Historically, the specific power of this sector has been decreasing and this was assumed to continue but at a slower rate of approximately 1% per annum (Table 6A.28). The use of gas was assumed to remain steady at 55% after 1995, as industry was assumed to switch away from conventional gas boilers to CHP systems (Table 6A.29(a)). Similarly, use of oil and solid fuel were assumed to decrease from approximately 2% each to negligible amounts over the next 30 years. The demand for heat from CHP systems was assumed to rise from 3% in 1995 to 5% in 2025. Electricity was also assumed to rise slightly, from 39% to 40% between 1995 and 2025.

Rubber and Plastics

The rubber and plastics industry sector was also assumed to increase its output at a rate similar to national rates of 2% per annum (Table 6A.26), with floor area increasing by 28% from 116,000 m^2 in 1995 to 148,000 m^2 in 2025 (Table 6A.27). The historical trend of a decreasing specific power was assumed to continue but at a slower rate of just under 1% per annum (Table 6A.28). The use of gas, electricity and heat from CHP were all assumed to increase from 41%, 39% and 10% in 1995 to 45%, 42% and 12% respectively. The use of oil was assumed to decrease from approximately 11% to as low as 3% by 2025. The use of solid fuel was assumed to be negligible throughout the 25-year period (Table 6A.29(a)).

Textiles

As with many other sub-sectors, the textile sector was assumed to grow at national average rates. This industry has been a small sector in Milton Keynes, with services and distribution being the main growth areas. As for other industrial sub-sectors, the fact that the city was 75% complete, leaving much less scope for expansion at the same rate as in the last 15 years, if new developments are restricted to within the designated area, was also taken into account when making assumptions regarding future growth rates. Linear growth rates were assumed for simplicity. Floor space was assumed to grow at a slower rate than the growth in output, to allow for an increase in output per unit of floor space. Floor space was assumed to be 35,000 m^2 in 2025, a rise of 10% from 1995 (Table 6A.27). The energy used to produce a unit of output was assumed to decrease by 16% over the next 30 years (Table 6A.28). It was assumed that electricity and gas usage would continue to decrease in this sector as CHP becomes more popular. Gas, electricity and CHP made up 52%, 32% and 16% of the demand for the textiles sector in 1995 respectively (Table 6A.29(a)). This was assumed to change to 50%, 30% and 20% for gas, electricity and CHP respectively in 2025. Use of oil and solid fuel in this sector is negligible.

6.2.1.5 Transport Sector

Freight Transport

Data on the index of monetary output for each of the sub-sectors from 1980 to 1995 was taken from the Annual Abstract of Statistics (CSO, 1980-1997). It was assumed that the index of output for each sub-sector within Milton Keynes was the same as that of the national index. The percentage of each energy source used by each mode was also taken from the same source and again it was assumed that Milton Keynes followed the national pattern. For CTC95, it was assumed that the index of output for the majority of the ten sub-sectors would increase at the national average growth rate of 2% per annum. Output from the Solid Fuel sector was assumed to decrease at a rate of 0.5% per annum over the period, reflecting the decline in use of solid fuels assumed for the domestic and non-domestic sectors.

The number of tonne-kilometres per year of freight transported nationally in each of the transport sub-sectors and the percentage of these tonne-kilometres that were accounted for by road, rail, water and pipeline were derived from data published in Transport Statistics (DoT, 1995). The national figures for the number of tonne-kilometres transported were adjusted for Milton Keynes using a figure based on the proportion of UK commercial floorspace (Herring, 1995) to that in the Council Area. As already mentioned, the number of tonne-kilometres of goods transported is assumed to increase in proportion to output. In general it was assumed that recent trends would continue.

All sectors, except petroleum and foodstuffs, were assumed to see a decreasing proportion of their freight being transported by rail, in line with the trend seen over previous years. No decreases were assumed for petroleum and foodstuffs, as negligible amounts of these goods are currently transported by this mode. The proportions of freight by rail for these sectors are given in Table 6A.30(a).

The transport of freight by water also generally decreased in line with past trends. For three sectors – metals, ores and metal wastes and foodstuffs – it was assumed that there would be no change in the proportion of these goods transported by water. Negligible amounts of ores and metal wastes, and foodstuff would continue to be transported by water.

Petroleum was the only product of which a significant amount was transported by pipeline in 1995. It was assumed that 20% of petroleum would continue to be transported by pipeline over the next 30 years. Road accounted for all remaining freight.

The number of tonne-kilometres of freight moved by each type of transport (road, rail, water, pipeline) is further sub-divided into the proportion transported by each fuel type before energy consumption is calculated. Historical data on this was derived from the annual abstract of statistics (CSO, 1980-1997). It was assumed that the proportions of the different types of fuel used are the same for Milton Keynes as nationally. In 1995, diesel accounted for 86% of fuel used by road freight, 67.5% of that used by rail freight and 81% of water freight fuel consumption. The rest of the fuel consumed by road freight was petrol, electricity for rail freight and fuel oil for water freight. Electricity was assumed to provide 100% of the power required to pump petroleum through pipelines. The only change in this assumed over the next 30 years was an increase in the amount of electricity used by rail freight, rising to 43% in 2010 and 57.5% in 2025, and subsequent decrease in diesel rail freight (Table 6A.31).

Data on the efficiency of each transport mode in MJ of delivered energy per tonne-kilometre travelled was obtained from Leach *et al* (1979). It was assumed that the efficiency of road transportation would increase by 30%, for rail and water by 17.5% and for pipelines by 12%, between 1995 and 2025 (Table 6A.32). The large increase in efficiency of road transport reflects the large amounts being invested in research and development on more efficient vehicles and the higher rate of turnover of road vehicles.

Personal Transport

The 1991 Census of population provided data on the fraction of the population of the Council Area living in urban areas and the number of car-owning households in both rural and urban areas. The percentage of households in Milton Keynes owning at least one car was assumed to increase, from 72% in 1995 to 78% in 2025 in the case of urban households, in line with UK Government projections of growth in car ownership (DoT, 1997).

Data on average vehicle load factor and average vehicle fuel efficiencies was obtained from Hughes (1993). Vehicle load factors, expressed as the number of passengers in each vehicle (in the case of cars, vans and motorcycles this includes the driver) were taken to be 25 passengers per bus, 260 passengers per train and 1.5 passengers per car in 1990 (Hughes, 1993). For this scenario it was assumed that as the car gains popularity as a means of transport, and with the general lack of funding in public transport and lack of co-ordination between service operators, the load factors of buses and trains are likely to continue to decrease in line with past trends (DoT, 1995), to 10 passengers per bus and 200 passengers per train by 2025 (Table 6A.33). With an increasing number of cars on the road and people having a desire for increased flexibility in transport (which they perceive the car to offer) it was assumed that the number of passengers per car would also decrease, to 1.2 in 2025.

The fuel consumption per vehicle-km of cars was assumed to remain constant, in line with recent trends where fuel efficiency improvements have been negated by increasing engine size (Table 6A.34). Improvements in fuel consumption per vehicle-km for buses and trains were assumed, due to the gradual replacement of vehicles by newer, more efficient ones. It was not assumed that consumers would purchase the most efficient vehicle on the market.

At present all of the buses in Milton Keynes run on petrol or diesel, as do most of its cars, vans and motorcycles. It was assumed that this would not change significantly in this scenario. The West coast mainline railway, which runs through the study area, has been electrified; the Bletchley-Bedford line has not been electrified. A proportion of rail journeys undertaken by residents of the Milton Keynes council area will be on electrified lines. The electrification programme seemed to have lost momentum so it was assumed that the proportion of energy required to fuel rail travel provided by electricity would not increase. It was assumed, therefore, that electricity would provide 25% of the total energy required by personal rail transport by 2025.

The National Travel Survey (DoT, 1996) was used to provide data on the number of journeys made per week for the different journey purposes and by different modes of travel, and the average length of each journey for urban areas and for rural areas. It was assumed that the total number of journeys travelled per person per month remained relatively constant. It was assumed that the number of journeys made by bus, bicycle and on foot would continue to decrease at similar rates to current national trends for towns of a similar size to Milton Keynes (Table 6A.35(a)). It was assumed that the majority of these journeys would be made by car in the future. Journeys by rail for work purposes was assumed to increase slightly, with people taking advantage of the fast links to London, whilst journeys by rail for shopping and leisure purposes were assumed to decrease slightly, as people take advantage of the city expansion and increased variety of leisure and shopping facilities. For this scenario it was assumed that journey length increases by 30% over 1990 levels by 2025, for bus, rail and car modes of travel (Table 6A.36(a)).

6.2.2 Fuel Switching Scenario

6.2.2.1 Services Sector

Assumptions made for the model parameters were the same as those made in the Current Trends Continued scenario except for those assumptions discussed below.

The use of electricity to provide space heating was assumed to decrease, falling back to 1980 levels by 2025. The use of oil and solid fuel were assumed to decrease to negligible amounts by 2025. The only fuel assumed to increase its share of this market was gas, through an increased use of gas-fired CHP, which was assumed to increase from providing 1% to 10% of the space heating energy demand between 1995 and 2025 respectively, in all sub-sectors except for Health. In the Health sub-sector, which already has a much higher use of CHP, it was assumed that CHP would supply 50% of that sub-sector's space heating demands by 2025. It was estimated that CHP schemes provided over 30% of the Health sub-sector space heating demand in 1995 (see Table 6A.7(b)).

Similar assumptions were made on the market share of each of the fuels supplying water heating demand. The market share of electricity supplying cooking demand was assumed to remain constant, supplying 25% of the energy demanded for cooking purposes in 2025. It was assumed that the use of oil and solid fuel would decrease to negligible amounts, with businesses switching to gas (Table 6A.7(b)).

The increased purchases of CHP and conventional gas appliances, caused by the changes outlined above, with companies switching from oil and solid fuel to gas and from gas to CHP, are assumed to lead to greater efficiency improvements than would otherwise be the case, as new appliances tend to be more efficient than older appliances. The efficiencies assumed for the different fuel types and systems are given in Table 6A.4.

6.2.2.2 Domestic Sector

In this sector the use of electricity to provide space heating was assumed to decrease, from 8% in 1995 to 5% in 2025 (Table 6A.15). The use of solid fuel decreased slightly between 1984 and 1995, from just under 5% to just over 1% in 1995. It was assumed that the use of solid fuel for space heating would continue to decrease, supplying less than 1% of total space heating in 2025. The use of CHP (gas-fired and biofuel-fired), through District Heating schemes, was assumed to increase from supplying approximately none of the space heating energy demand in 1995 to supplying 12% of the space heating energy demand in 2025. It was assumed that there would be some increases in the efficiency of fuel conversion appliances (such as boilers and CHP units) due to the replacement of older systems as a result of the fuel switching (Table 6A.19). It was assumed that the average efficiency of the CHP schemes would increase from 70% in 1995 to 80% in 2025. The average efficiency of gas space heating appliances was assumed to rise from 65% to 85% over the same period.

Similar assumptions were made on the market share of each of the fuels supplying water heating demand. It was assumed that the electricity supplied for water heating would account for 10% of the total water heating demand by 2025, a decrease from 13.5% in 1980. The use of oil and solid fuel was assumed to remain at 1995 levels as negligible amounts of these fuels were used (Table 6A.15).

It was assumed that approximately 1MWe of CHP plant would be installed in Milton Keynes by 2025 (Table 6A.20), with 25% of that plant burning biomass or landfill gas; the remaining 75% of plant was assumed to be gas fired (Table 6A.21). It was also assumed that 5MW of wind turbines would supply electricity to the sector via a locally owned "green" electricity supply company (Table 6A.22). The equivalent of 5% of the total domestic roof area in Milton Keynes was assumed to be covered with photovoltaic modules (Table 6A.23).

6.2.2.3 Industrial Sector

In the majority of industrial sub-sectors, the share of gas was assumed to increase, due to increased use of gas-fired CHP plant. It was assumed that the use of CHP would approximately double between 1995 and 2025 (Table 6A.29(b)). Electricity was assumed to retain its share of the total energy demand for each sub-sector. Both solid fuel and oil were assumed to decrease their market share to negligible amounts.

6.2.2.4 Transport Sector

Freight Transport

For the freight transport sub-sector it was assumed that approximately 5% of the total number of tonne-kilometres transported by road freight vehicles would be carried by vehicles running on CNG (Table 6A.32). These would be mainly vehicles supplying local delivery networks. No vehicle fuel efficiency increases significantly above those assumed for the Current Trends Continued scenario were assumed.

Personal Transport

As with the Current Trends Continued scenario the fuel efficiencies of all modes of personal transport were assumed to improve due to the gradual replacement of vehicles by newer, more efficient ones (Table 6A.34). In the Fuel Switching scenario, it was additionally assumed that some of these vehicles would be replaced by CNG and electric vehicles. It was assumed that approximately 8% of vehicles would run on CNG and 5% of vehicles would be electric by 2025. In addition, it was assumed that approximately 15% of buses would be either CNG or electric vehicles by 2025.

6.2.3 Technical Fix Scenario

6.2.3.1 Services Sector

Internal temperatures, fuel shares and floor areas were assumed to follow the same pattern as for the Current Trends Continued scenario, since these parameters are not affected by technological changes implemented to improve energy efficiency (Table 6A.3).

The heat loss parameter was assumed to reduce by 50% between 1995 and 2025 for the majority of the sub-sectors of the services sector. Those sub-sectors (for example personal services and commercial services) which already had relatively small heat loss parameters in 1995 were assumed to make smaller reductions in the amount of heat lost from their buildings, as it would be increasingly difficult and expensive for further reductions in heat loss to be made (see Table 6A.2).

The efficiency with which space heating and water heating appliances convert fuel to useful energy was assumed to increase by up to 30% over baseline year levels, depending upon the fuel type, the end use and the potential for improvement (Table 6A.4). Air conditioning demand was assumed to increase at a similar rate to that in the Current Trends Continued scenario (Table 6A.8), whilst the coefficient of performance of heat pumps in air conditioning equipment was assumed to increase from 2.5 to 3.0 between 1995 and 2025 (Table 6A.9).

The power consumed to provide a square metre of floor space with its hot water requirements was assumed to decrease by 33% over the 30 year period, due to increased levels of insulation (Table 6A.10). The power consumed to provide lighting was assumed to reduce by 50% due to increased use of energy efficient lighting and ballasts (Table 6A.5). As for the Current Trends Continued scenario, it was assumed that there would be no increase in demand per unit of floor area for end-use energy for these services. The specific power (power demand per m^2 of floor space) parameter for other purposes was assumed to increase at the same rate as in the Current Trends Continued scenario until 1995, and then start decreasing to reach 1990 levels by 2025 (Table 6A.6)

The demand for energy for street lighting was assumed to decrease by 25% by 2025, due to improvements in lighting efficiencies. It was assumed that lighting levels would not differ from those assumed in the Current Trends Continued scenario.

6.2.3.2 Domestic Sector

The efficiencies of cooking appliances (in terms of the useful energy output per unit of delivered energy) were assumed to increase from 11% in 1995 to 20% in 2025 for oil, solid fuel and gas, and from 20% to 40% for electrical cooking appliances, as old appliances were replaced with newer more efficient ones, such as, in the case of electric hobs, halogen hobs. The efficiencies of water heating appliances were assumed rise by 5% above the rises assumed in the Current Trends Continued scenario in 2025. The efficiencies of space heating appliances were assumed to rise to 85% by 2025, for those appliances converting gas and oil to heat. Electrical appliances were assumed to remain at 95% efficiency and solid fuel space heating appliance efficiencies were assumed to increase from 54% in 1995 to 74% by 2025 (Table 6A.19).

The average power demand for energy for lighting and appliances was assumed to increase from an estimated 284 watts per household in 1995 to 350 watts per household by 2025 (Table 6A.18), 17% lower than the demand for the same year in the Current Trends Continued scenario. The smaller increase in demand was mainly attributable to the increased energy efficiency of lighting and household appliances.

The average heat loss parameter of the dwellings was assumed to decrease to 1.75 $Wm^{-2}C^{-1}$ by 2025 (Table 6A.13). This figure was based on similar assumptions to those adopted in the Leicester Technical fix scenario (Boyle *et al*, 1994): all dwellings would have at least double glazing by 2025, with some having triple glazing; all dwellings would have 150 mm of loft insulation installed; all dwellings with cavity walls would have them filled; 25% of those without cavities would be internally insulated; the majority of purpose-built flats would be externally insulated, or have cavity-wall insulation; and better draught proofing (including edges of floors etc.) would be achieved in all dwellings.

6.2.3.3 Industrial Sector

The heat loss parameter of industrial buildings was assumed to decrease to 1.84 $Wm^{-2}C^{-1}$ by 2025 (Table 6A.25), a similar rate of decrease to that assumed for Leicester (Boyle *et al*, 1994). In all sub-sectors the energy consumption required to produce one unit of output was assumed to decrease, reaching a level of roughly 50% of that required in 1995 (Table 6A.28). All other assumptions were as those in the Current Trends Continued scenario.

6.2.3.4 Transport Sector

Freight Transport

Changes in the mode by which freight was transported were not considered to be technical fixes. For this reason, the modal changes envisaged in the Technical Fix scenario are the same as those in the Current Trends Continued scenario. The efficiency of each mode of freight transport was increased slightly in the Technical Fix scenario, to reach 40% above 1995 levels by 2025 for road transport, 25% above for rail and water, and 15% above for pipelines (Table 6A.31).

Personal Transport

It was assumed that further technical improvements to engines (within the limited scope allowed by the simple five year payback criterion) could lead to an improvement in engine efficiencies for all three modes of transport of 33% by 2025, compared to 1995 levels (Table 6A.34).

6.2.4 Local Agenda 21 (LA21) Scenario

6.2.4.1 Services Sector

For the majority of the services sub-sectors a reduction in the heat loss parameter of 50% was assumed to take place between 1995 and 2025 (Table 6A.2). However, for some of the small heat loss parameters (for example, personal services and commercial services), reductions as low as 20% were assumed over the period as it was felt the potential for savings from these were perhaps not as great.

In the Local Agenda 21 scenario, the use of gas to supply water heating was assumed to increase to 74% of the total energy requirements by 2025 whilst the use of Solid fuel and Oil would decrease to negligible amounts (Table 6A.7(c)). The share of heat from CHP and District Heating Schemes was also expected to rise to 10% by 2025. The share of water heating allocated to electricity was assumed to increase to 16% of the market share in 2025.

It was assumed that the use of electricity to provide space heating would continue to increase as a reflection of the increasing use of storage heaters and air conditioning in both public and commercial buildings (MK21 Steering Group, 1997). The only other fuel to increase its share of this market was heat from CHP and District Heating, which increases from 1% to 10% of the total. The use of solid fuel, oil and gas for space heating was assumed to decrease for all sub-sectors (see Table 6A.7(c)).

The specific power used for lighting decreases by 50% in this scenario this reflects the greater emphasis placed on the importance of energy efficient lighting in the Local Agenda 21 document on which this scenario was based (Table 6A.5). The specific power used for other purposes, such as electrical equipment and refrigeration, was assumed to decrease by 25% reflecting energy efficiency orientated purchasing policies of companies (Table 6A.6). Street lighting demand was assumed to decrease, due to improvements in efficiency.

6.2.4.2 Domestic Sector

It was assumed that the average heat loss parameter would decrease from 2.7 $Wm^{-2}C^{-1}$ in 1995 to 1.75 $Wm^{-2}C^{-1}$ in the year 2025 (Table 6A.13). The average heat loss parameter figure was based on the assumptions that from 1997 an NHER standard of 9.0 would be set for all new build, and that a standard of NHER 7.5 would be set for all refurbishments.

A small increase in the use of electricity for the purposes of water heating was assumed, due to the greater use of washing machines on cold fill, instant showers, etc., taking away some of the market held by gas in 1995 (Table 6A.15). For space heating and water heating demand the shares of oil and solid fuel decrease as those of district heating and CHP rise. CHP and district heating schemes are assumed to supply 7% of water and space heating demand by 2025, with just over 600kW_e of plant installed. It was assumed that approximately 10% of the CHP and District Heating schemes burned biofuels (Table 6A.21).

It was assumed for both water heating and space heating appliances that the efficiency of gas-fired and electrical appliances would increase at a rate slightly higher than that assumed for the Current Trends Continued scenario, as the energy advice centre assumed in the scenario encourages residents to get their appliances serviced more regularly and to install better controls (Table 6A.19).

The demand for energy for lighting and appliances per household was expected to increase by 25% between 1995 and 2025 due to increased levels of appliance ownership within households (Table 6A.18). This is a lower rate than that assumed in the Current Trends Continued scenario. In this scenario it was assumed that there would be a wider use of energy and eco-labelling of products in retail outlets, and through the work of the energy advice centre greater awareness of the possible savings from buying the more energy efficient appliances. It was assumed in the Local Agenda 21 scenario that the number of litres of hot water consumed per person returned to 1995 levels by 2025 (Table 6A.17).

A small number of wind turbines (10) were assumed to supply electricity to the sector (Table 6A.22). In addition, it was assumed that approximately 12,000 m^2 of roof space was covered with photovoltaic modules (equating to 0.4% of homes) (Table 6A.23) and that 0.2% of homes would be fitted with solar water heaters (Table 6A.16).

6.2.4.3 Industrial Sector

The heat loss parameter of buildings in the industry sector was assumed in the Current Trends Continued scenario to decrease from 4.0 $Wm^{-2}C^{-1}$ to 1.84 $Wm^{-2}C^{-1}$ over 45 years (Table 6A.25). It was assumed that similar standards to those set for the domestic sector would be set for industrial sector buildings.

The energy required to produce one unit of output was assumed to decrease at a faster rate than in recent historical trends, reaching 50% of the 1995 figure by 2025 (Table 6A.28).

It was assumed that there would be an increased uptake of CHP within the industrial sector, with many sub-sectors more than doubling their current installed capacity by 2025. The use of oil and solid fuel was assumed to continue to decline. Electricity was assumed to either hold a constant or an increasing share of the market, while the use of gas (other than as part of a CHP scheme) declined in the majority of sub-sectors, details are given in Table 6A.29(c)).

6.2.4.4 Transport Sector

Freight Transport

For the Local Agenda 21 scenario it has been assumed that the number of tonne-kilometres of transport traffic increases from 1990 levels (Table 6A.30(b)) but not as much as in Current Trends Continued. By 2025 the total number of tonne-kilometres was 10% less than in the Current Trends Continued scenario for the same year (Tables 6A.30(a) and (b)). This was assumed to be the result of companies using local suppliers where possible. It was also assumed that the use of roads to transport freight would decrease whilst the use of rail and water for freight transport would increase.

Personal Transport

It was assumed the load factors of buses and trains continued to decrease but at a slower rate than assumed in the Current Trends Continued scenario based on initiatives and the vision for Milton Keynes outlined in the Local Agenda 21 document for Milton Keynes (MK21 Steering Group, 1997). It was assumed that the number of passengers per car would rise to 2 passengers per vehicle, as car share and taxi share schemes were initiated (Table 6A.33).

Based on targets and policy suggested outlined in the Local Agenda 21 document (MK21 Steering Group, 1997) supporting greater use of electric and compressed natural gas (CNG) powered vehicles, it was assumed that by 2025, 7% of buses would be using CNG, and 5% powered by electricity. For car travel it was assumed that 5% of cars would be CNG, and 3% electric.

The Local Agenda 21 scenario assumed that the total number of journeys travelled per person per month decreased over time (Table 6A.35(b)), through combining trips in line with specified policies and targets (MK21 Steering Group, 1997). Mode choice was also assumed to change, with the number of journeys made by bus increasing, reaching almost 1980 levels by 2025. The number of journeys made by rail was also assumed to increase, reaching 1990 levels by 2025. It was assumed that the majority of these journeys would previously have been made by car.

This scenario also assumes that journey lengths would decrease substantially due to careful planning of the location of facilities, companies recruiting locally, and due to residents choosing to support local produce and businesses through their choice of purchases (Table 6A.36(b)).

6.2.5 Green Scenario

6.2.5.1 Services Sector

In this scenario, the heat loss parameter of buildings in the services sector was assumed to reduce to 70% of 1990 levels by 2025 (Table 6A.2). As with the other scenarios, those sub-sectors where heat loss parameters are already relatively low were reduced by a smaller percentage. None of the sub-sectors was assumed to have an heat loss parameter of less than 0.75 $Wm^{-2}C^{-1}$ in the year 2025. In this scenario it was assumed that the required mean monthly internal temperature of the buildings would remain constant after 1995, at 17C (Table 6A.3).

The efficiency of appliances used for water heating was assumed to increase to between 60% and 85% by 2025, depending upon the type of fuel being used. Similarly, space heating efficiencies reached 85% for all fuel types, with the exception of electrical appliances, which were assumed to have an efficiency of 95% in all three scenarios, constant over time (Table 6A.4). Cooking appliance efficiencies rose from between 11% and 20% in 1990 to between 30% and 40% in 2025.

The power consumed to provide a unit of floor area with its cooking and hot water requirements was assumed to reduce by 50%, as people become more aware of the need to reduce wastage. The power consumed per unit of floor area to provide lighting requirements would also decrease, as buildings would be designed to make greater use of natural daylight and better controls are installed (Table 6A.5). The specific power used to provide other services within the Services sector was assumed to continue rising until around the year 1995, at a similar rate to that in the Current Trends Continued scenario, and then to decrease to 75% of 1990 levels by 2025, due to increased efficiency of appliances and better energy management (Table 6A.6). The demand for street lighting was assumed to decrease by 50% due to better planning, more efficient lights and controls and the acceptability of lower levels of lighting.

The rate at which building floor areas increase was assumed to be the same as for the Current Trends Continued scenario, as it was assumed that the new town would continue to be developed to completion (Table 6A.1). The use of air conditioning in Service sector buildings was assumed to continue to increase to the year 2025, but at about half the rate in the Current Trends Continued scenario, due to an increased use of passive cooling and natural ventilation (Table 6A.8). The coefficient of performance of air conditioning plant was assumed to increase from 2.5 in 1995 to 3.5 by 2025 (Table 6A.9).

It was assumed that, in those few businesses where oil was used as a fuel for cooking, there would be a move towards using electricity (Table 6A.7(d)). This choice would be based upon the availability of electricity from renewable sources. For space heating and water heating, it was assumed there would be a movement away from oil, and that Combined Heat and Power and District Heating would replace this (Table 6A.7(d)).

It was estimated that by 2025 an equivalent of 10% of all service sector roof space in Milton Keynes would be used for the installation of photovoltaic modules. A significant part of the sector's electricity requirements were assumed to be met by renewable sources, such as wind farms. It would obviously not be economically viable to site these within the Council Area, but rather in windier areas elsewhere in the UK. Ten wind farms were assumed by 2025, each containing 20 turbines with a rated power of approximately 300 kW per turbine. Fifty percent of the solid fuel used to provide the services sector with energy was assumed to come from biofuels such as refuse-derived fuels and waste. Additionally, half of the fuel being consumed to provide CHP and District Heating was assumed to come from biofuels by 2025.

6.2.5.2 Domestic Sector

It was assumed that the population would grow at a slightly slower rate than in the Current Trends Continued scenario, reaching 240,000 instead of 262,000 by 2025 (Table 6A.12). It was also assumed that residents would utilise space more economically, thus halting the decline in the size of households (people per household) that occurs in the other two scenarios.

The average heat loss parameter was assumed to reduce to 1.25 $Wm^{-2}C^{-1}$ (Table 6A.13), based on the following assumptions: the mix of housing would change, with more terraced housing and flats being built; all dwellings would have at least triple glazing, as is now obligatory in Sweden; all dwellings would be draught proofed to a high standard; all dwellings would have at least 150 mm of loft insulation installed; 100% of cavity walls would be filled; 75% of dwellings without cavity walls would be internally insulated; all high rise flats would be externally insulated; and 75% of dwellings would have floor insulation installed.

The required internal temperature of houses in winter was assumed to remain constant at 16.2C, after 1995 (Table 6A.14). The demand for energy for lighting and appliances was assumed to remain constant after 1995. This would occur because people would choose to purchase the most energy-efficient appliances available and would also choose to buy fewer appliances once a certain level of ownership had been reached.

It was assumed that the demand for hot water would remain constant after 1995 (Table 6A.17). Additionally it was assumed that the temperature to which the water is heated in the tank would also decrease to 1980 levels by 2025. This would be due to better lagging of tanks and pipes, better use and understanding of controls and a wider use of instant water heaters. It was expected that 10% of households would use solar water heaters.

By 2025, the efficiency of cooking appliances was assumed to increase to 30% for gas, oil and solid fuel, whilst for electrical cooking appliances the efficiency was assumed to rise to 45% (Table 6A.19). The efficiency of all space heating appliances was expected to reach 85% by 2020, due to the widespread use of condensing boilers; and the efficiency of water heating was assumed to reach between 60% and 95% depending on the type of fuel.

It was assumed that the use of oil for the purposes of space heating, water heating and cooking would decrease. The use of solid fuel (as a percentage of the total domestic sector demand) was assumed to remain constant, half of this demand being supplied by biofuels by 2025. The use of electricity as a percentage of the total energy demand of the domestic sector would increase over time, as households opt to use electricity supplied by CHP and renewable sources (Table 6A.15).

It was assumed that 5% of the total domestic roof area is utilised for photovoltaic modules by the year 2025 (Table 6A.23). Additional electricity would be supplied to the domestic sector, in the green scenario, by the equivalent of 100 wind turbines each with a rated power of approximately 600 kW (Table 6A.22). The use of CHP and District Heating would also increase (Table 6A.20). Biofuels (such as refuse derived fuels, waste and wood chips) would provide for approximately half of the power for the CHP and District Heating schemes (Tables 6A.21 and 6A.24).

6.2.5.3 Industrial Sector

It was assumed that production output from the industrial sector followed a similar trend to that in the Current Trends Continued scenario, since output is affected by national demand and not local demand. Heavy industry and industries producing large amounts of pollutants were assumed to be discouraged from establishing within the Council Area and therefore increases in output from these sectors would be at a slower rate (i.e. 0.5% per annum instead of 1% to 2%) (Table 6A.26).

The rate at which floor area increases was assumed to be the same as for the Current Trends Continued scenario, as it was assumed that the new town would continue to be developed to completion (Table 6A.27). The average heat loss parameter of the buildings in each sub-sector was assumed to decrease to 1.25 $Wm^{-2}C^{-1}$; again, a rate similar to that for the domestic sector (Table 6A.25).

Electricity consumption was assumed to remain constant on the whole, since although an effort was assumed to be made by industry to purchase efficient appliances and use these appliances in the most efficient manner possible, it was assumed that more appliances would still be used (Table 6A.29(d)).

Fuel switching away from oil and solid fuel to gas and heat (CHP and District Heating) was assumed to continue to occur (Table 6A.29(d)). The use of CHP and District Heating was assumed to be more popular than in the Current Trends Continued and

Technical Fix scenarios, as local companies share resources in an effort to make District Heating and CHP viable[14].

Additionally, energy was assumed to be supplied from photovoltaic panels installed on the roofs and south facing walls of buildings (the equivalent of approximately 5% of the total roof area was assumed to be used for this purpose by 2025), and from wind farms of a similar size to those used to supply electricity to the other sectors. Around 50% of the solid fuel consumed, and 50% of the fuel used to provide CHP and district heating, was assumed to be provided by biofuels.

6.2.5.4 Transport Sector

Freight Transport

It was assumed that in the Green scenario the use of rail and water to transport freight would increase, particular for heavy loads, or freight being transported long distances (Table 6A.30(c)). However, for transporting freight over short distances and for small loads it was assumed that road would still be the only solution.

In this scenario, it was assumed that there would be a 50% increase on 1995 levels of efficiency by 2025 for road transport, a 33% increase for rail and water, and a 20% increase for pipelines (Table 6A.31). It was assumed that the index of production for the majority of the freight transport sub-sectors would decrease by 30% of 1995 levels by 2025.

Personal Transport

In the Green Scenario, people were assumed to think more carefully about car ownership; to be more aware of the benefits of public transport and the disadvantages of the car. For this reason the model assumed that the level of car ownership remained constant after 1995.

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14 At present the model cannot handle energy flows between sectors, e.g. a CHP plant supplying electricity and some heat to a factory while supplying the heating requirements of a nearby swimming pool in the services sector.

Load factors for rail and bus were also assumed not to decrease but to remain constant after 1995 (Table 6A.33). It was assumed that car load factors would increase to just over two car passengers per vehicle by 2025.

As in the Current Trends Continued scenario, it was assumed that there was no significant change in the total number of journeys travelled per person per month (Table 6A.35(c)). However, for the majority of journey purposes, the number of journeys undertaken by cycling and walking was assumed to increase to 40% above 1995 levels by 2025. (In the case of those household not owning cars, the rise for walking was less (20% in some cases) as these households already made a significant number of journeys on foot). The number of bus and rail journeys was also increased significantly, to the detriment of car travel.

For car, rail and bus transport it was assumed that the average journey length would decrease from 1995 by 1% per annum (Table 6A.36(c)).

It was assumed that by 2025, 5% of buses would be using CNG, and 5% powered by electricity. Much of the electricity would be imported from wind farms or hydroelectric schemes, or supplied by photovoltaic cells installed on the roofs of garages and car parks. The proportion of rail transport using electricity increased to 25%, part of which was also supplied by renewables, and for car travel it was assumed that 5% of cars would be fuelled by CNG, and 5% electric (also partly supplied by PV and wind or hydro power).

ANNEX TO CHAPTER SIX

6A.1 SERVICES SECTOR

						Floor Area (m^2)
		2025				
Sector	**1995**	**CTC95**	**FSW**	**TFX**	**LA21**	**GRN**
Offices	343,000	463,000	463,000	463,000	463,000	429,000
Shops	420,000	567,000	567,000	567,000	567,000	525,000
Distribution	310,000	419,000	419,000	419,000	419,000	388,000
Commercial Services	88,000	119,000	119,000	119,000	119,000	110,000
Leisure	110,000	149,000	149,000	149,000	149,000	138,000
Residential	35,000	47,000	47,000	47,000	47,000	44,000
Personal Services	12,000	16,000	16,000	16,000	16,000	15,000
Government	60,000	80,000	80,000	80,000	80,000	74,000
Defence	5,000	7,000	7,000	7,000	7,000	6,000
Education	260,000	351,000	351,000	351,000	351,000	325,000
Health	78,000	105,000	105,000	105,000	105,000	97,000
Catering	42,000	57,000	57,000	57,000	57,000	53,000

Table 6A.1: Service Sector Floor Area by Sub-Sector and Scenario, 1995-2025

						Heat Loss ($Wm^{-2}C^{-1}$)
		2025				
Sector	**1995**	**CTC95**	**FSW**	**TFX**	**LA21**	**GRN**
Offices	1.89	1.42	1.42	0.95	0.95	0.75
Shops	1.55	1.16	1.16	0.78	0.78	0.75
Distribution	2.17	1.63	1.63	1.09	1.09	0.75
Commercial Services	1.14	0.99	0.99	0.88	0.88	0.75
Leisure	3.66	2.75	2.75	1.83	1.83	1.10
Residential	2.34	1.76	1.76	1.17	1.17	0.75
Personal Services	1.18	1.03	1.03	0.91	0.91	0.75
Government	3.95	2.96	2.96	1.98	1.98	1.19
Defence	4.60	3.45	3.45	2.3	2.3	1.38
Education	2.84	2.13	2.13	1.42	1.42	0.85
Health	4.85	3.64	3.64	2.43	2.43	1.46
Catering	1.90	1.43	1.43	0.95	0.95	0.75

Table 6A.2: Service Sector Heat Loss Parameters by Sub-Sector and Scenario, 1995-2025

		Celsius
	2025	
1995	**CTC95**	**GRN**
16.2	18.0	16.2

Table 6A.3: Mean Internal Air Temperature for the CTC95 and GRN Scenarios, 1995-2025

						Efficiency
		2025				
System	**1995**	**CTC95**	**FSW**	**TFX**	**LA21**	**GRN**
Space heating						
Conventional Gas	0.67	0.75	0.85	0.85	0.80	0.85
Conventional Oil	0.76	0.80	0.80	0.85	0.80	0.85
Conventional Solid Fuel	0.54	0.60	0.60	0.65	0.60	0.85
Electric	0.95	0.95	0.95	0.95	0.95	0.95
Gas CHP	0.75	0.80	0.85	0.85	0.85	0.85
Water heating						
Conventional Gas	0.50	0.60	0.70	0.70	0.70	0.85
Conventional Oil	0.39	0.45	0.45	0.48	0.45	0.60
Conventional Solid Fuel	0.36	0.40	0.40	0.45	0.40	0.60
Electric	0.85	0.85	0.85	0.95	0.85	0.95
Gas CHP	0.75	0.80	0.85	0.85	0.85	0.85
Cooking						
Gas/Oil/Solid Fuel	0.11	0.15	0.15	0.20	0.20	0.30
Electric	0.20	0.25	0.25	0.35	0.35	0.40

Table 6A.4: Service Sector end use system efficiencies by main appliance, fuel type and by scenario, 1995-2025

						Wm^{-2}
		2025				
Sector	**1995**	**CTC95**	**FSW**	**TFX**	**LA21**	**GRN**
Offices	4.37	3.06	3.06	2.19	3.06	2.19
Shops	4.37	3.06	3.06	2.19	3.06	2.19
Distribution	1.53	1.07	1.07	0.77	1.07	0.77
Commercial Services	4.25	2.98	2.98	2.13	2.98	2.13
Leisure	9.05	6.34	6.34	4.53	6.34	4.53
Residential	5.00	3.50	3.50	2.50	3.50	2.50
Personal Services	2.26	1.58	1.58	1.13	1.58	1.13
Government	3.05	2.14	2.14	1.53	2.14	1.53
Defence	5.90	4.13	4.13	2.95	4.13	2.95
Education	1.20	0.84	0.84	0.60	0.84	0.60
Health	2.95	2.07	2.07	1.48	2.07	1.48
Catering	7.04	4.93	4.93	3.52	4.93	3.52

Table 6A.5: Milton Keynes Service Sector Lighting Specific Power Demand by Sector and Scenario, 1995-2025

Wm⁻²						
		2025				
Sector	**1995**	**CTC95**	**FSW**	**TFX**	**LA21**	**GRN**
Offices	5.25	5.64	5.64	3.94	5.64	3.94
Shops	7.28	7.49	7.49	5.46	7.49	5.46
Distribution	1.30	1.36	1.36	0.98	1.36	0.98
Commercial Services	3.50	3.71	3.71	2.63	3.71	2.63
Leisure	9.18	9.46	9.46	6.88	9.46	6.88
Residential	4.24	4.41	4.41	3.18	4.41	3.18
Personal Services	3.45	3.61	3.61	2.59	3.61	2.59
Government	1.87	1.97	1.97	1.40	1.97	1.40
Defence	2.03	2.26	2.26	1.52	2.26	1.52
Education	0.61	0.63	0.63	0.46	0.63	0.46
Health	3.75	3.88	3.88	2.81	3.88	2.81
Catering	0.04	0.05	0.05	0.03	0.05	0.03

Table 6A.6: Milton Keynes Service Specific Power Demand for Other Services by Sector and Scenario, 1995-2025

Share of Total Demand				
	Health		**All Other Sectors**	
System	**1995**	**2025**	**1995**	**2025**
Space heating				
Conventional Gas	0.54	0.45	0.85	0.83
Conventional Oil	0.02	0.01	0.02	0.01
Solid fuel	0.02	0	0.02	0
Electric	0.10	0.14	0.10	0.14
Gas CHP	0.32	0.40	0.01	0.02
Water Heating				
Conventional Gas	0.52	0.43	0.83	0.81
Conventional Oil	0.02	0.01	0.02	0.01
Solid fuel	0.02	0	0.02	0
Electric	0.12	0.16	0.12	0.16
Gas CHP	0.32	0.40	0.01	0.02
Cooking				
Gas	0.70	0.65	0.70	0.65
Oil	0.025	0	0.025	0
Solid Fuel	0.025	0	0.025	0
Electric	0.25	0.35	0.25	0.35

Table 6A.7(a): End use demand by system and fuel type (as fraction of total demand for each end use), 1995-2025 for the CTC95 Scenario

				Share of Total Demand
	Health		**All Other Sectors**	
System	**1995**	**2025**	**1995**	**2025**
Space heating				
Conventional Gas	0.54	0.42	0.85	0.82
Conventional Oil	0.02	0	0.02	0
Solid Fuel	0.02	0	0.02	0
Electric	0.10	0.08	0.10	0.08
Gas CHP	0.32	0.50	0.01	0.10
Water Heating				
Conventional Gas	0.52	0.40	0.83	0.80
Conventional Oil	0.02	0	0.02	0
Solid Fuel	0.02	0	0.02	0
Electric	0.12	0.10	0.12	0.10
Gas CHP	0.32	0.50	0.01	0.10
Cooking				
Gas	0.70	0.75	0.70	0.75
Oil	0.025	0	0.025	0
Solid Fuel	0.025	0	0.025	0
Electric	0.25	0.25	0.25	0.25

Table 6A.7(b): End use demand by system and fuel type for the Fuel Switching Scenario (FSW), 1995-2025

				Share of Total Demand
	Health		**All Other Sectors**	
System	**1995**	**2025**	**1995**	**2025**
Space heating				
Conventional Gas	0.54	0.36	0.85	0.76
Conventional Oil	0.02	0	0.02	0
Solid fuel	0.02	0	0.02	0
Electric	0.10	0.14	0.10	0.14
Gas CHP	0.32	0.50	0.01	0.10
Water Heating				
Conventional Gas	0.52	0.34	0.83	0.74
Conventional Oil	0.02	0	0.02	0
Solid fuel	0.02	0	0.02	0
Electric	0.12	0.16	0.12	0.16
Gas CHP	0.32	0.50	0.01	0.10
Cooking				
Gas	0.70	0.65	0.70	0.65
Oil	0.025	0	0.025	0
Solid Fuel	0.025	0	0.025	0
Electric	0.25	0.35	0.25	0.35

Table 6A.7(c): End use demand by system and fuel type for Local Agenda 21 (LA21) Scenario, 1995-2025

				Share of Total Demand
	Health		All Other Sectors	
System	1995	2025	1995	2025
Space heating				
Conventional Gas	0.54	0.36	0.85	0.75
Conventional Oil	0.02	0	0.02	0
Solid Fuel	0.02	0	0.02	0
Electric	0.10	0.14	0.10	0.16
Gas CHP	0.32	0.50	0.01	0.09
Water Heating				
Conventional Gas	0.52	0.34	0.83	0.70
Conventional Oil	0.02	0	0.02	0
Solid Fuel	0.02	0	0.02	0
Electric	0.12	0.16	0.12	0.20
Gas CHP	0.32	0.50	0.01	0.10
Cooking				
Gas	0.70	0.65	0.70	0.65
Oil	0.025	0	0.025	0
Solid Fuel	0.025	0	0.025	0
Electric	0.25	0.35	0.25	0.35

Table 6A.7(d): End use demand by system and fuel type for the Green Scenario (GRN), 1995-2025

						Percent
		2025				
Sector	1995	CTC95	FSW	TFX	LA21	GRN
Offices	19	37	37	37	37	28
Shops	22	44	44	44	44	33
Distribution	2	4	4	4	4	3
Commercial Services	5	10	10	10	10	8
Leisure	1	2	2	2	2	2
Residential (Hotels etc.)	4	8	8	8	8	6
Personal Services	2	4	4	4	4	3
Government	4	8	8	8	8	6
Defence	1	1	1	1	1	1
Education	4	8	8	8	8	6
Health	7	14	14	14	14	10
Catering	1	1	1	1	1	1

Table 6A.8: The Percent of Milton Keynes Service Sector Floor Area Served by Air-Conditioning by Sub-Sector and Scenario, 1995-2025

					Coefficient of Performance
	2025				
1995	CTC95	FSW	TFX	LA21	GRN
2.5	2.5	2.5	3.0	3.0	3.5

Table 6A.9: Air Conditioning Coefficient of Performance

						Wm^{-2}
		2025				
Sector	**1995**	**CTC95**	**FSW**	**TFX**	**LA21**	**GRN**
Offices	0.98	0.73	0.73	0.65	0.73	0.49
Shops	0.38	0.28	0.28	0.25	0.28	0.19
Distribution	0.77	0.57	0.57	0.51	0.57	0.38
Commercial Services	0	0	0	0	0	0
Leisure	7.54	5.66	5.66	5.05	5.66	3.77
Residential	7.50	5.63	5.63	5.03	5.63	3.75
Personal Services	1.13	0.85	0.85	0.76	0.85	0.57
Government	4.27	3.20	3.20	2.86	3.20	2.14
Defence	11.88	8.91	8.91	7.96	8.91	5.94
Education	3.89	2.92	2.92	2.61	2.92	1.95
Health	19.90	14.90	14.90	13.33	14.90	9.95
Catering	7.04	5.28	5.28	4.72	5.28	3.52

Table 6A.10: Milton Keynes Service Sector Water Heating Specific Power Demand by Sector and Scenario, 1995-2025

						Wm^{-2}
		2025				
Sector	**1995**	**CTC95**	**FSW**	**TFX**	**LA21**	**GRN**
Offices	0.49	0.37	0.37	0.33	0.37	0.24
Shops	0.38	0.28	0.28	0.25	0.28	0.19
Distribution	0	0	0	0	0	0
Commercial Services	0	0	0	0	0	0
Leisure	4.53	3.40	3.40	3.04	3.40	2.27
Residential	9.17	6.88	6.88	6.14	6.88	4.59
Personal Services	0.38	0.29	0.29	0.25	0.29	0.19
Government	1.83	1.37	1.37	1.23	1.37	0.92
Defence	3.96	2.97	2.97	2.65	2.97	1.98
Education	1.79	1.34	1.34	1.20	1.34	0.90
Health	5.90	4.43	4.43	3.95	4.43	2.95
Catering	38.70	29.03	29.03	25.93	29.03	19.35

Table 6A.11: Milton Keynes Service Sector Cooking Specific Power Demand by Sector and Scenario, 1995-2025

6A.2 Domestic Sector

		2025	
	1995	**CTC95**	**GRN**
Resident Population	196,000	262,000	240,000
Household Size *(persons per household)*	2.54	2.28	2.54

Table 6A.12: Population and Household Size 1995-2025 for the Current Trends Continued (CTC95) and Green (GRN) Scenarios

$Wm^{-2}C^{-1}$					
	2025				
1995	CTC95	FSW	TFX	LA21	GRN
2.70	2.00	2.00	1.75	1.75	1.25

Table 6A.13: Domestic Sector Heat Loss Parameter by scenario, 1995-2025

Celsius					
	2025				
1995	CTC95	FSW	TFX	LA21	GRN
17	18	18	18	18	17

Table 6A.14: Mean Internal Air Temperature

Share of Total Demand						
		2025				
System	**1995**	**CTC95**	**FSW**	**TFX**	**LA21**	**GRN**
Space heating						
Conventional Gas	0.91	0.94	0.82	0.94	0.89	0.94
Conventional Oil	0.00	0.00	0.00	0.00	0.00	0.00
Conventional Solid Fuel	0.01	0.01	0.01	0.01	0.01	0.01
Electric	0.08	0.05	0.05	0.05	0.05	0.00
Heat	0.00	0.00	0.12	0.00	0.05	0.05
Water heating						
Conventional Gas	0.89	0.90	0.78	0.90	0.83	0.90
Conventional Oil	0.00	0.00	0.00	0.00	0.00	0.00
Conventional Solid Fuel	0.00	0.00	0.00	0.00	0.00	0.00
Electric	0.11	0.10	0.10	0.10	0.12	0.05
Heat	0.00	0.00	0.12	0.00	0.05	0.05
Cooking						
Gas	0.56	0.54	0.54	0.54	0.54	0.54
Oil/Solid Fuel	0.01	0.01	0.01	0.01	0.01	0.01
Electric	0.44	0.45	0.45	0.45	0.45	0.45

Table 6A.15: Domestic sector end use system shares by main appliance, fuel type and by scenario, 1995-2025

Percent					
	2025				
1995	CTC95	FSW	TFX	LA21	GRN
0.08	0.16	10.00	0.16	0.18	10.00

Table 6A.16: The Percent of Households in Milton Keynes with Solar Water Heaters by Scenario, 1995-2025

						litres
		2025				
	1995	**CTC95**	**FSW**	**TFX**	**LA21**	**GRN**
Baseline Hot Water Demand Per Household	38.5	57.5	57.5	47.5	47.5	38.5
Additional Hot Water Demand Per Person in each Household	24.0	36.0	36.0	30.0	30.0	24.0

Table 6A.17: Domestic Sector Hot Water Demand 1995-2025 for the Current Trends Continued (CTC95) and Green (GRN) Scenarios

					Watts
	2025				
1995	**CTC95**	**FSW**	**TFX**	**LA21**	**GRN**
284	424	424	350	350	284

Table 6A.18: Electricity demand for Lighting and Appliances per Household by scenario, 1995-2025

						Efficiencies
		2025				
System	**1995**	**CTC95**	**FSW**	**TFX**	**LA21**	**GRN**
Space heating						
Conventional Gas	0.65	0.78	0.85	0.85	0.80	0.85
Conventional Oil	0.74	0.78	0.78	0.85	0.78	0.85
Conventional Solid Fuel	0.54	0.60	0.60	0.74	0.60	0.85
Electric	0.95	0.95	0.95	0.95	0.95	0.95
Heat	0.75	0.80	0.85	0.85	0.85	0.85
Water heating						
Conventional Gas	0.60	0.70	0.75	0.75	0.75	0.85
Conventional Oil	0.39	0.45	0.45	0.50	0.45	0.60
Conventional Solid Fuel	0.36	0.40	0.40	0.50	0.40	0.60
Electric	0.85	0.90	0.90	0.95	0.90	0.95
Heat	0.70	0.75	0.80	0.80	0.80	0.80
Cooking						
Gas/Oil/Solid Fuel	0.11	0.15	0.15	0.20	0.15	0.30
Electric	0.20	0.35	0.35	0.40	0.35	0.45

Table 6A.19: Domestic sector end use system efficiencies by main appliance, fuel type and by scenario, 1995-2025

					MW_e
	2025				
1995	**CTC95**	**FSW**	**TFX**	**LA21**	**GRN**
0	0	1	0	0.6	0.6

Table 6A.20: Capacity of CHP Installed to Supply the Domestic Sector by Scenario, 1995-2025

						Fuel Shares (%)
Fuel	**1995**	**2025**				
		CTC95	**FSW**	**TFX**	**LA21**	**GRN**
Biomass	0%	-	25%	-	10%	50%
Natural Gas	100%	-	75%	-	90%	50%

Table 6A.21: CHP Fuel Shares for the Domestic Sector by Scenario, 1995-2025

					MW
1995	**2025**				
	CTC95	**FSW**	**TFX**	**LA21**	**GRN**
0	0	60	0	3	60

Table 6A.22: Installed wind turbine capacity to supply the domestic sector by scenario, 1995-2025

					Percent
1995	**2025**				
	CTC95	**FSW**	**TFX**	**LA21**	**GRN**
0%	0%	5%	0%	2%	5%

Table 6A.23: Percent of domestic sector roof space devoted to photovoltaic systems by scenario, 1995-2025

					Percent
1995	**2025**				
	CTC95	**FSW**	**TFX**	**LA21**	**GRN**
0%	0%	25%	0%	50%	50%

Table 6A.24: Percent of domestic sector solid fuel demand met by Biofuels, 1995-2025

6A.3 Industrial Sector

					$Wm^{-2}C^{-1}$
1995	**2025**				
	CTC95	**FSW**	**TFX**	**LA21**	**GRN**
3.50	2.80	2.80	1.84	1.84	1.25

Table 6A.25: The heat loss parameter of Industrial Sector Buildings by scenario, 1995-2025

			£s per second
		2025	
Sector	**1995**	**CTC95**	**GRN**
Ceramics	0.18	0.18	0.18
Chemicals	1.47	1.91	1.62
Construction	0.55	0.55	0.55
Engineering	7.64	9.93	9.93
Food, Drink	2.48	3.22	3.22
Metals	1.25	1.63	1.63
Others	0.55	0.72	0.83
Paper	1.84	2.39	2.39
Rubber, Plastics	2.14	2.78	2.78
Textiles	0.31	0.40	0.40
Vehicles	2.46	3.20	3.20

Table 6A.26: Industrial Sector Output of Production by Sub-Sector and Scenario, 1995-2025

			Floor Area (m^2)
		2025	
Sector	**1995**	**CTC95**	**GRN**
Ceramics	2,000	2,000	2,000
Chemicals	50,000	70,000	50,000
Construction	8,000	8,000	8,000
Engineering	205,000	250,000	250,000
Food, Drink	32,000	40,000	40,000
Metals	78,000	90,000	90,000
Others	27,000	30,000	50,000
Paper	37,000	50,000	50,000
Rubber, Plastics	107,000	150,000	150,000
Textiles	31,000	35,000	35,000
Vehicles	27,000	35,000	35,000

Table 6A.27: Industrial Sector Floor Area by Sub-Sector and Scenario, 1995-2025

						Watts per £ Output
		2025				
Sector	**1995**	**CTC95**	**FSW**	**TFX**	**LA21**	**GRN**
Ceramics	20.0	15.0	15.0	10.0	10.0	6.0
Chemicals	11.0	8.3	8.3	5.5	5.5	3.3
Construction	11.0	8.3	8.3	5.5	5.5	3.3
Engineering	5.0	3.8	3.8	2.5	2.5	1.5
Food, Drink	8.2	6.2	6.2	4.1	4.1	2.5
Metals	14.0	10.5	10.5	7.0	7.0	4.2
Others	4.1	3.1	3.1	2.1	2.1	1.2
Paper	21.0	15.8	15.8	11.0	11.0	6.3
Rubber, Plastics	16.0	12.0	12.0	8.0	8.0	4.8
Textiles	4.2	3.2	3.2	2.1	2.1	1.3
Vehicles	6.4	4.8	4.8	3.2	3.2	1.9

Table 6A.28: Industrial Sector Specific Power Demand by Sub-Sector and Scenario, 1995-2025

										Percent
	Electricity		**Gas**		**Oil**		**Solid Fuel**		**CHP Heat**	
Sector	**1995**	**2025**	**1995**	**2025**	**1995**	**2025**	**1995**	**2025**	**1995**	**2025**
Ceramics	13	13	79	76	3	0	0	0	5	11
Chemicals	26	30	46	52	1	0	18	3	9	15
Construction	31	41	49	49	18	10	2	0	0	0
Engineering	32	38	46	24	0	0	0	0	22	36
Food, Drink	25	28	62	64	10	0	0	0	4	8
Metals	19	22	71	65	1	0	0	0	9	15
Others	37	45	36	39	19	6	0	0	8	10
Paper	38	40	55	55	2	0	2	0	2	5
Rubber, Plastics	38	42	40	45	12	3	0	0	8	10
Textiles	32	30	52	50	0	0	0	0	16	20
Vehicles	24	29	41	41	19	6	0	0	17	24

Table 6A.29(a): Industrial Sector Fuel Mix by Sub-Sector for the CTC95 and TFX Scenarios, 1995-2025

Sector	Electricity		Gas		Oil		Solid Fuel		CHP Heat	
										Percent
	1995	2025	1995	2025	1995	2025	1995	2025	1995	2025
Ceramics	13	13	79	72	3	0	0	0	5	15
Chemicals	26	26	46	54	1	0	18	0	9	20
Construction	31	31	49	69	18	0	2	0	0	0
Engineering	32	32	46	23	0	0	0	0	22	45
Food, Drink	25	25	62	63	10	0	0	0	4	12
Metals	19	19	71	63	1	0	0	0	9	18
Others	37	37	36	48	19	0	0	0	8	14
Paper	38	38	55	54	2	0	2	0	2	8
Rubber, Plastics	38	38	40	48	12	0	0	0	8	15
Textiles	32	32	52	43	0	0	0	0	16	25
Vehicles	24	24	41	46	19	0	0	0	17	30

Table 6A.29(b): Industrial Sector Fuel Mix by Sub-Sector for the FSW Scenario, 1995-2025

Sector	Electricity		Gas		Oil		Solid Fuel		CHP Heat	
										Percent
	1995	2025	1995	2025	1995	2025	1995	2025	1995	2025
Ceramics	13	13	79	72	3	0	0	0	5	15
Chemicals	26	30	46	50	1	0	18	3	9	20
Construction	31	41	49	49	18	10	2	0	0	0
Engineering	32	38	46	25	0	0	0	0	22	45
Food, Drink	25	28	62	60	10	0	0	0	4	12
Metals	19	22	71	63	1	0	0	0	9	18
Others	37	45	36	35	19	6	0	0	8	14
Paper	38	40	55	52	2	0	2	0	2	8
Rubber, Plastics	38	42	40	40	12	3	0	0	8	15
Textiles	32	30	52	45	0	0	0	0	16	25
Vehicles	24	29	41	35	19	6	0	0	17	30

Table 6A.29(c): Industrial Sector Fuel Mix by Sub-Sector for the LA21 Scenario, 1995-2025

Sector	Electricity		Gas		Oil		Solid Fuel		CHP Heat	
										Percent
	1995	2025	1995	2025	1995	2025	1995	2025	1995	2025
Ceramics	13	13	79	72	3	0	0	0	5	15
Chemicals	26	26	46	54	1	0	18	0	9	20
Construction	31	31	49	69	18	0	2	0	0	0
Engineering	32	32	46	23	0	0	0	0	22	45
Food, Drink	25	25	62	63	10	0	0	0	4	12
Metals	19	19	71	63	1	0	0	0	9	18
Others	37	37	36	49	19	0	0	0	8	14
Paper	38	38	55	54	2	0	2	0	2	8
Rubber, Plastics	38	38	40	47	12	0	0	0	8	15
Textiles	32	32	52	43	0	0	0	0	16	25
Vehicles	24	24	41	46	19	0	0	0	17	30

Table 6A.29(d): Industrial Sector Fuel Mix by Sub-Sector for the GRN Scenario, 1995-2025

6A. 4 TRANSPORT SECTOR

6A.4.1 Freight Transport

	Mode Share *(%)*				Goods transported *(Tonne-km)*
	Road	**Rail**	**Water**	**Pipe**	
Agricultural Products					
1995	94	3	4	0	45,710
2025	67	2	1	0	55,644
Chemicals					
1995	91	5	4	0	36,007
2025	95	2	3	0	43,832
Fertilisers					
1995	85	8	8	0	8,280
2025	93	4	4	0	10,079
Foodstuffs					
1995	99	1	0	0	87,108
2025	99	1	0	0	106,038
Machines and Miscellaneous Products					
1995	85	8	7	0	162,573
2025	91	4	5	0	197,902
Metal Products					
1995	78	19	3	0	33,938
2025	84	13	3	0	41,313
Minerals and Building Materials					
1995	81	7	13	0	101,770
2025	85	4	11	0	123,886
Ores and Metal Wastes					
1995	59	41	0	0	8,280
2025	67	33	0	0	10,079
Petroleum Products					
1995	10	3	70	17	252,268
2025	16	3	64	17	307,090
Solid Fuels					
1995	35	39	27	0	52,179
2025	42	35	23	0	63,518

Table 6A.30(a): Freight Transport – Goods Transported and Mode Share by Sub-sector for the CTC95, FSW and TFX Scenarios, 1995-2025

	Mode Share				Goods transported (Tonne-km)
	Road	**Rail**	**Water**	**Pipe**	
Agricultural Products					
1995	0.94	0.03	0.04	0	45,710
2025	0.67	0.02	0.01	0	50,080
Chemicals					
1995	0.91	0.05	0.04	0	36,007
2025	0.95	0.02	0.03	0	39,449
Fertilisers					
1995	0.85	0.08	0.08	0	8,280
2025	0.93	0.04	0.04	0	9,071
Foodstuffs					
1995	0.99	0.01	0	0	87,108
2025	0.99	0.01	0	0	95,434
Machines and Miscellaneous Products					
1995	0.85	0.08	0.07	0	162,573
2025	0.91	0.04	0.05	0	178,112
Metal Products					
1995	0.78	0.19	0.03	0	33,938
2025	0.84	0.13	0.03	0	37,182
Minerals and Building Materials					
1995	0.81	0.07	0.13	0	101,770
2025	0.85	0.04	0.11	0	111,497
Ores and Metal Wastes					
1995	0.59	0.41	0	0	8,280
2025	0.67	0.33	0	0	9,071
Petroleum Products					
1995	0.1	0.03	0.7	0.17	252,268
2025	0.16	0.03	0.64	0.17	276,381
Solid Fuels					
1995	0.35	0.39	0.27	0	52,179
2025	0.42	0.35	0.23	0	57,166

Table 6A.30(b): Freight Transport – Goods Transported and Mode Share by Sub-sector for the LA21 Scenario, 1995-2025

	Mode Share				Goods transported (Tonne-km)
	Road	**Rail**	**Water**	**Pipe**	
Agricultural Products					
1995	0.94	0.03	0.04	0.00	45710
2025	0.78	0.11	0.11	0.00	31997
Chemicals					
1995	0.91	0.05	0.04	0.00	36007
2025	0.66	0.17	0.17	0.00	14403
Fertilisers					
1995	0.85	0.08	0.08	0.00	8280
2025	0.64	0.22	0.14	0.00	3312
Foodstuffs					
1995	0.99	0.01	0.00	0.00	87108
2025	0.76	0.12	0.12	0.00	60976
Machines and Miscellaneous Products					
1995	0.85	0.08	0.07	0.00	162573
2025	0.68	0.16	0.16	0.00	113801
Metal Products					
1995	0.78	0.19	0.03	0.00	33938
2025	0.57	0.31	0.12	0.00	23756
Minerals and Building Materials					
1995	0.81	0.07	0.13	0.00	101770
2025	0.67	0.17	0.16	0.00	71239
Ores and Metal Wastes					
1995	0.59	0.41	0.00	0.00	8280
2025	0.44	0.56	0.00	0.00	3312
Petroleum Products					
1995	0.10	0.03	0.70	0.17	252268
2025	0.07	0.02	0.74	0.17	100907
Solid Fuels					
1995	0.35	0.39	0.27	0.00	52179
2025	0.32	0.40	0.28	0.00	36525

Table 6A.30(c): Freight Transport: Goods Transported and Mode Share by Sub-sector for the GRN Scenario, 1995-2025

Percent						
		2025				
Mode & Fuel	**1995**	**CTC95**	**FSW**	**TFX**	**LA21**	**GRN**
Road						
DERV	86	86	83	86	84	86
Gasoline	14	14	12	14	7	14
Electric	0	0	0	0	4	0
CNG	0	0	5	0	5	0
Rail						
DERV	70	40	40	40	40	40
Electric	30	60	60	60	60	60
Water						
DERV	81	81	81	81	81	81
Fuel Oil	19	19	19	19	19	19
Pipeline						
Electricity	100	100	100	100	100	100

Table 6A.31: Fuel Shares by Mode and Scenario, 1995-2025

MJ per tonne-km						
		2025				
Mode	**1995**	**CTC95**	**FSW**	**TFX**	**LA21**	**GRN**
Road	3.60	2.48	2.48	2.20	2.48	1.80
Rail	1.00	0.83	0.83	0.75	0.83	0.67
Water	1.90	1.57	1.57	1.40	1.57	1.27
Pipeline	1.00	0.88	0.88	0.85	0.88	0.80

Table 6A.32: Fuel Efficiency by Mode and Scenario, 1995-2025

6A.4.2 Personal Transport

Passengers per Vehicle			
		2025	
	1995	**CTC95**	**GRN**
Car	1.5	1.2	1.5
Bus	17.50	10.00	17.50
Rail	255	200	255

Table 6A.33: Vehicle Occupancy by Mode for CTC95 and GRN Scenarios, 1995-2025

Jkm^{-1}						
		2025				
Mode	**1995**	**CTC95**	**FSW**	**TFX**	**LA21**	**GRN**
Car	4.72	4.72	4.72	4.05	4.72	4.05
Bus	24.50	21.15	21.15	16.40	21.15	16.40
Rail	92.0	78.50	78.50	68.50	78.50	68.50

Table 6A.34: Fuel Consumption per Vehicle-Km by Mode and by Scenario, 1995-2025

Journeys per Person per Week									
		Urban				**Rural**			
		Car		**No Car**		**Car**		**No Car**	
Purpose	**Mode**	**1995**	**2025**	**1995**	**2025**	**1995**	**2025**	**1995**	**2025**
Work	Car	19.81	24.80	2.26	3.05	20.65	23.85	2.68	3.28
	Bus	1.38	0.23	2.99	2.30	0.76	0.22	1.39	1.03
	Rail	0.85	0.32	0.94	0.72	0.24	0.03	0.01	0.00
Shopping	Car	33.93	37.50	6.41	8.47	34.84	40.75	7.52	8.75
	Bus	0.38	0.05	4.92	3.69	0.16	0.01	2.67	1.78
	Rail	0.18	0.03	0.67	0.38	0.08	0.02	0.43	0.22
Leisure	Car	12.25	14.90	1.86	2.85	13.26	15.40	3.26	4.23
	Bus	0.59	0.14	5.13	4.62	0.17	0.01	4.02	3.18
	Rail	0.06	0.01	0.23	0.03	0.01	0.01	0.09	0.01

Table 6A.35(a): Mean Number of Journeys made per Person per Week for Urban and Rural Car Owning and Non-Car Owning Households by Mode, Purpose for CTC95, FSW and TFX Scenarios, 1995-2025

Journeys per Person per Week									
		Urban				**Rural**			
		Car		**No Car**		**Car**		**No Car**	
Purpose	**Mode**	**1995**	**2025**	**1995**	**2025**	**1995**	**2025**	**1995**	**2025**
Work	Car	19.81	5.81	2.26	2.11	20.65	10.06	2.68	2.58
	Bus	1.38	5.24	2.99	3.08	0.76	2.89	1.39	1.45
	Rail	0.85	3.35	0.94	0.97	0.24	1.19	0.01	0.03
Shopping	Car	33.93	23.63	6.41	6.11	34.84	26.14	7.52	7.26
	Bus	0.38	1.78	4.92	5.10	0.16	0.65	2.67	2.83
	Rail	0.18	0.72	0.67	0.73	0.08	0.25	0.43	0.48
Leisure	Car	12.25	5.30	1.86	1.68	13.26	9.37	3.26	3.08
	Bus	0.59	1.88	5.13	5.24	0.17	0.73	4.02	4.13
	Rail	0.06	0.23	0.23	0.27	0.01	0.20	0.09	0.14
TOTAL	*ALL*	*69.43*	*47.94*	*25.41*	*25.29*	*70.17*	*51.48*	*22.07*	*21.98*

Table 6A.35(b): Mean Number of Journeys made per Person per Week for Urban and Rural Car Owning and Non-Car Owning Households by Mode, Purpose for LA21 Scenario, 1995-2025

Journeys per Person per Week									
		Urban				**Rural**			
		Car		**No Car**		**Car**		**No Car**	
Purpose	**Mode**	**1995**	**2025**	**1995**	**2025**	**1995**	**2025**	**1995**	**2025**
Work	Car	19.81	18.82	2.26	0.18	20.65	20.47	2.68	2.14
	Bus	1.38	1.92	2.99	3.29	0.76	1.06	1.39	1.53
	Rail	0.85	1.19	0.94	1.03	0.24	0.34	0.01	0.01
Shopping	Car	33.93	31.45	6.41	3.89	34.84	35.07	7.52	5.26
	Bus	0.38	0.05	4.92	5.41	0.16	0.22	2.67	2.94
	Rail	0.18	0.03	0.67	0.74	0.08	0.11	0.43	0.47
Leisure	Car	12.25	11.05	1.86	0.02	13.26	13.88	3.26	1.12
	Bus	0.59	1.05	5.13	5.65	0.17	0.24	4.02	4.42
	Rail	0.06	0.08	0.23	0.26	0.01	0.01	0.09	0.10
TOTAL	*ALL*	*69.43*	*65.64*	*25.41*	*20.47*	*70.17*	*71.4*	*22.07*	*17.99*

Table 6A.35(c): Mean Number of Journeys made per Person per Week for Urban and Rural Car Owning and Non-Car Owning Households by Mode, Purpose for the Green Scenario, 1995-2025

Kilometres									
		Urban				**Rural**			
		Car		**No Car**		**Car**		**No Car**	
Purpose	**Mode**	**1995**	**2025**	**1995**	**2025**	**1995**	**2025**	**1995**	**2025**
Work	Car	11.48	18.60	0.98	1.69	19.68	30.00	11.99	19.20
	Bus	6.76	5.00	7.76	9.65	2.28	0.85	5.85	6.09
	Rail	62.81	81.58	15.14	19.67	119.14	154.74	50.29	73.50
Shopping	Car	9.14	11.87	2.00	4.00	12.97	19.60	12.81	19.10
	Bus	10.78	7.56	22.94	27.15	0.07	0.00	6.38	6.85
	Rail	107.95	140.21	61.17	79.44	67.26	87.36	27.31	35.47
Leisure	Car	6.30	11.60	0.85	1.50	1.58	2.98	9.32	14.90
	Bus	9.15	8.10	17.89	22.35	0.40	0.03	6.15	6.75
	Rail	111.86	145.28	28.68	37.25	64.70	84.00	32.81	42.62

Table 6A.36(a): Mean Journey Length for Urban and Rural Car Owning and Non-Car Owning Households by Mode, Purpose for CTC95, FSW and TFX Scenarios, 1995-2025

									Kilometres
		Urban				**Rural**			
		Car		**No Car**		**Car**		**No Car**	
Purpose	**Mode**	**1995**	**2025**	**1995**	**2025**	**1995**	**2025**	**1995**	**2025**
Work	Car	11.48	15.99	0.98	2.96	19.68	13.68	11.99	8.73
	Bus	6.76	5.00	7.76	2.24	2.28	2.72	5.85	5.51
	Rail	62.81	15.68	15.14	3.69	119.14	101.20	50.29	42.75
Shopping	Car	9.14	10.73	2.00	2.15	12.97	9.17	12.81	98.20
	Bus	10.78	5.36	22.94	10.25	0.07	0.39	6.38	5.98
	Rail	107.95	47.50	61.17	25.52	67.26	57.13	27.31	23.67
Leisure	Car	6.30	5.98	0.85	1.48	1.58	1.19	9.32	6.86
	Bus	9.15	4.43	17.89	7.86	0.40	0.62	6.15	5.70
	Rail	111.86	95.00	28.68	12.21	64.70	54.92	32.81	26.82

Table 6A.36(b): Mean Journey Length for Urban and Rural Car Owning and Non-Car Owning Households by Mode, Purpose for the LA21 Scenario, 1995-2025

									Kilometres
		Urban				**Rural**			
		Car		**No Car**		**Car**		**No Car**	
Purpose	**Mode**	**1995**	**2025**	**1995**	**2025**	**1995**	**2025**	**1995**	**2025**
Work	Car	11.48	8.04	0.98	0.69	19.68	13.78	11.99	8.39
	Bus	6.76	4.73	7.76	5.43	2.28	1.59	5.85	4.12
	Rail	62.81	43.97	15.14	10.60	119.14	83.40	50.29	35.20
Shopping	Car	9.14	6.40	2.00	1.40	12.97	9.08	12.81	8.97
	Bus	10.78	7.55	22.94	16.06	0.07	0.05	6.38	4.47
	Rail	107.95	75.57	61.17	42.82	67.26	47.08	27.31	19.12
Leisure	Car	6.30	5.83	0.85	0.60	1.58	1.10	9.32	6.52
	Bus	9.15	6.41	17.89	12.52	0.40	0.28	6.15	4.31
	Rail	111.86	78.30	28.68	20.08	64.70	45.29	32.81	22.97

Table 6A.36(c): Mean Journey Length for Urban and Rural Car Owning and Non-Car Owning Households by Mode, Purpose for the Green Scenario, 1995-2025

SCENARIO ASSESSMENT

7.1 INTRODUCTION

The scenarios described in Chapter Six were modelled and appraised using the methodology given in Chapter Five. The results of this process are discussed below, beginning with a discussion of the results of the appraisal. This is followed by an assessment of the methodology used.

7.2 ENERGY USE

7.2.1 Current Trends Continued Scenario (CTC95)

In the Current Trends Continued Scenario, the total delivered energy consumption of Milton Keynes was estimated to increase by 49%, from 11.9 PJ in 1990 to 17.6 PJ in 2025 (Table 7.1). This rise is mainly due to substantial increases in energy consumption within the transport sector, increased standards of heating in domestic residences and increased use of appliances in general.

						PJ
		2025				
Sector	**1990**	**CTC95**	**FSW**	**TFX**	**LA21**	**GRN**
Electricity	2.39	4.24	4.00	3.00	4.43	3.20
Natural Gas	6.10	8.67	8.51	5.42	6.07	2.87
Oil	2.72	4.89	4.87	4.05	2.04	1.13
Solid Fuel	0.28	0.05	0.02	0.07	0.04	0.00
BioFuels	0.00	0.00	0.06	0.00	0.09	0.07
TOTAL	11.86	17.63	16.97	13.76	12.67	6.53

Table 7.1 Total Delivered Energy by Fuel and by Scenario, 1990 to 2025

The percentage shares of different energy sources did not change greatly between 1990 and 2025. The use of solid fuel decreased whilst the use of electricity, oil and gas increased (Table 7.1). The majority of electricity was supplied from the national grid. The percentage of electricity generated locally from Combined Heat and Power (CHP) was estimated to contribute to 4% of the total electricity demand in 1990; this rose to 5% by 2025.

In 1990 the total annual delivered energy demand was divided between the sectors as follows: domestic sector, 33%, services sector, 20%, industrial sector, 29% and transport, 17%. By 2025 it was estimated that the domestic sector annual demand would have increased by 56% (to 6.17 PJ), the services sector demand would have increased by 22% (to 2.94 PJ) and the industrial sector annual demand would have decreased by 8% (to 3.16 PJ). Thus in 2025 it was estimated that the total delivered energy demand would be split between the sectors as follows: domestic sector, 35%, services sector, 17%, industrial sector, 18% and transport, 30%.

						PJ
		2025				
Sector	**1990**	**CTC95**	**FSW**	**TFX**	**LA21**	**GRN**
Domestic	3.95	6.17	5.89	5.11	4.81	2.03
Services	2.41	2.94	2.91	2.05	2.79	1.86
Industry	3.45	3.16	3.15	2.18	3.04	1.43
Transport	2.05	5.36	5.02	4.42	2.03	1.21
TOTAL	11.86	17.63	16.97	13.76	12.67	6.53

Table 7.2 Total Delivered Energy by Sector and by Scenario, 1990 to 2025.

7.2.2 Fuel Switching Scenario (FSW)

In the Fuel Switching Scenario, the total delivered energy consumption of Milton Keynes was estimated to increase by 43%, from 11.9 PJ in 1990 to 17.0 PJ in 2025. As with the Current Trends Continued Scenario, as substantial part of this rise was due to increases in the transport sector.

The percentage shares of different energy sources did not change greatly between 1990 and 2025. The use of solid fuel decreased to a negligible amount in 2025, whilst the use of gas increased by 40% above 1990 levels. It was assumed that there would be a small amount of biomass in use in 2025, either from refuse derived fuels (RDFSW), waste, or coppicing. It was assumed that this would be burned in either small-scale CHP schemes, or in an incineration plant with heat recovery. The most dramatic increases in fuel shares occurred in electricity and oil consumption, which were estimated to increase by 67% and 79% respectively over the 35 year time period. The percentage of electricity generated locally from Combined Heat and Power (CHP) was estimated to contribute to 8% of the total electricity demand in 2025, double the share in 1990. Renewable sources accounted for 40% of delivered electricity.

By 2025 it was estimated that the domestic sector annual demand for energy would have increased by 49% (to 5.89 PJ) from 1990 levels; the services sector demand would have increased by 21% (to 2.91 PJ); the industrial sector annual demand would have decreased by 9% (to 3.15 PJ) and energy demand in the transport sector would have increased by 145% (to 5.02 PJ) (see Table 7.2). Thus in 2025 it was estimated that the total delivered energy demand would be substantially unchanged from the 2025 Current Trends Continued case, split between the four sectors as follows: domestic sector, 35%, services sector, 17%, industrial sector, 19% and transport, 30%.

7.2.3 Technical Fix Scenario (TFX)

The total annual delivered energy demand in this scenario was estimated to increase from 11.9 PJ in 1990 to 13.8 PJ in 2025, an increase of approximately 16%. This increase is less than the increase in economic activity expected within the Council Area over the same period.

As in the Current Trends Continued Scenario, the use of solid fuels decreased. However, the use of both electricity and oil increased; in this scenario electricity demand increased by 25% but gas demand decreased by 11% as a result of savings made from heating buildings, i.e. improved insulation. This was reflected in the fuel split which was estimated to be 24%, 43%, 32% and 1% for electricity, gas, oil and solid fuel respectively in 2025. In 1990 the fuel split was estimated to be 21%, 53%, 24% and 2% for electricity, gas, oil and solid fuels respectively. As with the Current Trends Continued Scenario, a small amount of biomass usage by 2025 was assumed. This contributed less than 1% to the total energy supplied in 2025.

The domestic sector energy demand was estimated to increase by 29% from 1990 levels, to 5.11 PJ in 2025, due to increases in population and decreases in household size. However, this is half the increase expected in the Current Trends Continued (CTC95) Scenario. Transport sector energy demand also increased from 1990 levels, to 4.42 PJ in 2025 – a substantial increase over 1990 levels (Table 7.2). The energy demand of the services and industrial sectors decreased over the same time period by 15% (to 2.05 PJ) and 37% (to 2.18 PJ) respectively. This had the result of changing the relative shares of total energy demand to 37%, 15%, 16% and 32% for the domestic, services, industrial and transport sectors respectively.

7.2.4 Local Agenda 21 Scenario (LA21)

In the Local Agenda 21 Scenario, the total delivered energy consumption of Milton Keynes was estimated to increase by just 7% from 1990 levels, to 12.7 PJ in 2025. This rise is mainly due to increased standards of heating in domestic residences and from increased use of appliances in both the domestic and services sectors.

The use of both solid fuels and oil decreased whilst the use of electricity , oil and natural gas increased. It was assumed that there would be a small amount of biomass fuel in use in 2025, supplying 1% of demand, either from refuse derived fuels (RDFSW), waste, or coppicing. As in the Fuel Switching Scenario, it was assumed that this would be burned in either small-scale combined heat and power schemes,. The most dramatic increase in fuel shares occurred in electricity consumption, which was estimated to increase by 85% over the 35 year time period. The majority of electricity was supplied from the national grid. The percentage of electricity generated locally from Combined Heat and Power (CHP) was estimated to contribute to 4% of the total electricity demand in 1990: this rose to 5% by 2025.

By 2025 it was estimated that the domestic sector annual energy demand would have increased by 22% (to 4.81 PJ), the services sector demand would have increased by 16% (to 2.79 PJ), the industrial sector annual demand was estimated to decrease by 12% (to 3.04 PJ), and the transport sector to have decreased by 1% (to 2.03 PJ) (Table 7.2). Thus in 2025 it was estimated that the total delivered energy demand would be split between the sectors as follows: domestic sector, 38%, services sector, 22%, industrial sector, 24% and transport, 16%.

7.2.5 Green Scenario (GRN)

In this scenario a decrease of approximately 45%, to 6.5 PJ, was seen to occur in the total annual delivered energy demand for the Council Area between 1990 and 2025.

Living standards continued to rise, though not as rapidly as in the previous two scenarios.

Again the already low use solid fuel (excluding biofuels) decreased by 98% to a negligible amount. The use of electricity increased by 44%, to 3.2 PJ, over the time period, and its importance in terms of its contribution to total demand increased, to 44% of annual demand. In this scenario 46% of the electricity supplied to the Council Area in 2025 was estimated to come from locally owned or locally contracted[15] companies, generating electricity from renewable sources, particularly wind, photovoltaics and biomass, the majority of the biomass being used to power CHP units. The demand for gas decreased by 53%, to 2.8 PJ by 2025; 39% of the total energy demand for 2025 was supplied by gas. Fourteen percent of the gas supplied to the Council Area was estimated to be burned in CHP units by 2025. Oil demand decreased by 58%.

It was estimated that there would be a decrease in the amount of energy required by all four sectors between 1990 and 2025. Domestic sector energy demand decreased by 49%, to 2.03 PJ; industrial sector demand decreased by 59% to 1.43 PJ, services sector demand by 23% to 1.86 PJ, and transport sector demand by 41% to 1.21 PJ (Table 7.2). Thus the relative shares of the total demand by 2025 were estimated to be 31%, 28%, 22% and 19% for the domestic, services, industrial and transport sectors respectively.

7.3 The Wider Impacts

This section presents the non-energy impacts of the energy scenarios, in particular emissions, land-use, and monetary costs.

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[15] For some of the renewable energy sources it is not possible to locate the generation plant locally (e.g. wind turbines). It was assumed that a number of local companies and housing associations and co-operatives would purchase their electricity directly from companies generating all the electricity they supply from renewable sources.

7.3.1 Energy Expenditure

Monetary costs were evaluated for a range of fuel prices using the methodology described in Chapter 5. Table 7.3 shows the total amount of quantity purchased between January 1990 and December 2025 and its value, calculated on the basis described above. As discussed above, a discount rate of 5% was used. Figures are given in 1990 £s.

	MILTON KEYNES (1990 to 2025)				
	CTC95	TFX	GRN	LA21	FSW
Primary Energy Consumption *(PJ)*	566	497	394	491	649
Energy Expenditure *(£million 1990)*	£3,505 to £3,990	£3,170 to £3,591	£2,418 to £2,729	£3,077 to £3,472	£3,930 to £4,562

Table 7.3: Total Energy Purchased in Milton Keynes by Scenario, 1990 to 2025.

It should be noted that energy expenditure has been calculated using the market price and not the marginal cost of energy supply (CSERGE, 1992). The market price and therefore the energy expenditure may be higher than the marginal cost for a variety of reasons. If the market is not truly competitive, then distortions may occur. Additionally, policies may be in place (e.g. NFFO) that attempt to internalise some of the external costs of energy.

£million (1990)					
	MILTON KEYNES (1990 to 2025)				
	CTC95	TFX	GRN	LA21	FSW
Energy Taxes and Duties paid	£1,150 to £1,188	£1,063 to £1,097	£748 to £770	£906 to £934	£1,100 to £1,133

Table 7.4: Total Taxes and Duties Paid on Energy Purchased by Milton Keynes by Scenario, 1990 to 2025

The total estimated value of taxes and duties paid on energy purchases made between 1990 and 2025 amounts is given in Table 7.4. As can be seen from the tables, although the Fuel Switching Scenario leads to a higher level of consumption of primary energy, and a higher value of the energy purchased than in the Current Trends Continued Scenario, less taxes are paid. This is due to switching from a highly taxed fuel in the transport sector to electricity and CNG, which are less heavily taxed.

£million (1990)					
	MILTON KEYNES (1990 to 2025)				
	CTC95	**TFX**	**GRN**	**LA21**	**FSW**
Capital Investment	£106 to £1147	£191 to £1685	£396 to £4922	£204 to £1500	£131 to £1262

Table 7.5: Capital Invested in Energy Management by Milton Keynes by Scenario, 1990 to 2025

Capital investment in energy efficiency technologies has been calculated as a range of costs: the exact figure will depend on the choice of supplier of individual technologies and precise specifications. As can be seen from Table 7.5, continuation of current trends (CTC95) would be likely to lead to the lowest level of capital expenditure on energy technology, whilst the Green Scenario is potentially the most expensive.

£million (1990)					
	MILTON KEYNES (1990 to 2025)				
	CTC95	**TFX**	**GRN**	**LA21**	**FSW**
Total Expenditure	£3611 to £5137	£3361 to £5276	£2814 to £7651	£3281 to £4972	£4061 to £5824

Table 7.6: Total Expenditure 1990 to 2025 by Scenario

The Local Agenda 21 Scenario involved lower total expenditure (fuel costs + capital costs over the 35 year period) than Current Trends Continued Scenario (Table 7.6). The Current Trends Continued Scenario had the highest fuel costs. The performance of the scenarios in terms of total monetary costs was dominated by capital costs. The Green Scenario had the highest range of possible costs.

In terms of total monetary outlay, at the lowest end of the cost range all the scenarios except fuel switching implied less outlay than the Current Trends Continued Scenario, with the Green Scenario implying the lowest monetary outlay. At the upper end of the costs range only the Local Agenda 21 Scenario out performed Current Trends Continued, whilst the Green Scenario would cost significantly more than any other scenario.

7.3.2 Greenhouse Gas Emissions

As can be seen from Table 7.7 the Fuel Switching and Local Agenda 21 Scenarios produce higher levels of greenhouse gas emissions (expressed in terms of CO_2

equivalent) than those in the Current Trends Continued scenario. In both cases this is a because of measures to improve local air quality resulting in an increase in carbon dioxide emissions.

					Units CO_2 equivalent
	MILTON KEYNES (1990 to 2025)				
	CTC95	**TFX**	**GRN**	**LA21**	**FSW**
GWP	55.59	50.45	43.69	57.75	58.67

Table 7.7: Global Warming Potential of Greenhouse Gas Emissions by Scenario, 1990 to 2025.

7.3.3 Local Air Pollution

This section presents the results for each scenario in terms of emissions that are produced locally (within the borough) and will affect local air quality. Without using a dispersion model it is difficult to predict the precise effects that these emissions will have on local air quality. However, it is reasonably safe to assume the higher the emissions of these pollutants the poorer the local air quality is liable to become.

					Thousand Tonnes
	MILTON KEYNES (1990 to 2025)				
	CTC95	**TFX**	**GRN**	**LA21**	**FSW**
Sulphur Dioxide	95.00	82.91	58.22	73.51	90.34
Nitrous Oxides	33.47	33.91	24.90	31.66	37.14
Carbon Monoxide	3.67	3.64	2.72	3.59	3.97
Particulates	2.81	2.44	1.74	2.23	2.67

Table 7.8: Local Air Polluting Emissions by Scenario 1990-2025

The Green Scenario produces the lowest levels of local air pollutants (Table 7.8). The Fuel Switching Scenario shows the least improvement compared with Current Trends Continued, and actually results in an increase in the emissions of some pollutants.

7.3.4 Acid Rain

Without information on the weather, chimney stack heights and the measures in place at each power station to prevent sulphur dioxide and other gases being emitted into the atmosphere, it is difficult to quantify the amount of acid deposition likely to occur as a result of adopting the different energy scenarios considered here. It is even more difficult to assess how much damage will occur to specific ecosystems as a result of that acid deposition (see Chapter 2 for more details). However, the levels of sulphur dioxide emissions from power stations in each scenario provide a useful indicator of relative impacts.

				Thousand Tonnes
MILTON KEYNES (1990 to 2025)				
CTC95	**TFX**	**GRN**	**LA21**	**FSW**
112.04	120.61	92.51	124.03	105.87

Table 7.9: Sulphur Dioxide Emissions from Power Stations Resulting from Energy Consumption in Milton Keynes by Scenario, 1990-2025.

Two scenarios result in reduced power station sulphur dioxide emissions compared with current trends continued – the Green Scenario and the Fuel Switching Scenario (Table 7.9). This is due to the assumption in both scenarios that a higher proportion of electricity would be generated locally through the use of CHP. Additionally, in the Green Scenario some renewables were included. The Local Agenda 21 Scenario results in an increase in sulphur dioxide emissions from power stations, as a result of a greater demand for electricity.

7.3.5 Other Impacts

Other impacts from each of the scenarios are listed in Tables 7.10 to 7.14. These include job creation, increased comfort levels and reduction of fuel poverty as the results of the energy efficiency programmes in the Technical Fix, Green and Local Agenda 21 Scenarios.

All the scenarios would require additional land. For the Current Trends Continued Scenario and the Fuel Switching Scenario additional generating capacity is likely to be required to meet the growth in electricity demand that is not met from CHP or renewables. Three of the scenarios – Fuel Switching, Local Agenda 21 and Green – require small amounts of additional land to site wind turbines. Both the new power plants and the wind turbines will have some visual impact on the areas surrounding them. These impacts can be minimised with careful siting and, in the case of power plants, use of landscaping. Some minor noise pollution would also be expected in all five scenarios, though little of this would affect the residents of Milton Keynes directly. However, waste incineration, which is part of the Fuel Switching, Local Agenda 21 and Green Scenarios, can produce unpleasant odours if the process is not properly managed.

The manufacturing of photovoltaic modules requires use of several hazardous materials, in extremely small quantities. However, the risk is no greater than that of many other manufacturing processes, and safety standards are in place to minimise the risk to workers. This affects the Fuel Switching, Local Agenda 21 and Green Scenarios, which include significant contributions from PV. There is a fire risk when handling petroleum products, natural gas, coal (from coal dust) and wood chips. Coal dust and dust from wood chips also pose a health hazard and can cause lung damage if not handled correctly. This risk is present in all five scenarios as the use of fossil fuels continues in all of them. The hazards from wood chips are an issue for the Fuel Switching, Local Agenda 21 and Green Scenarios.

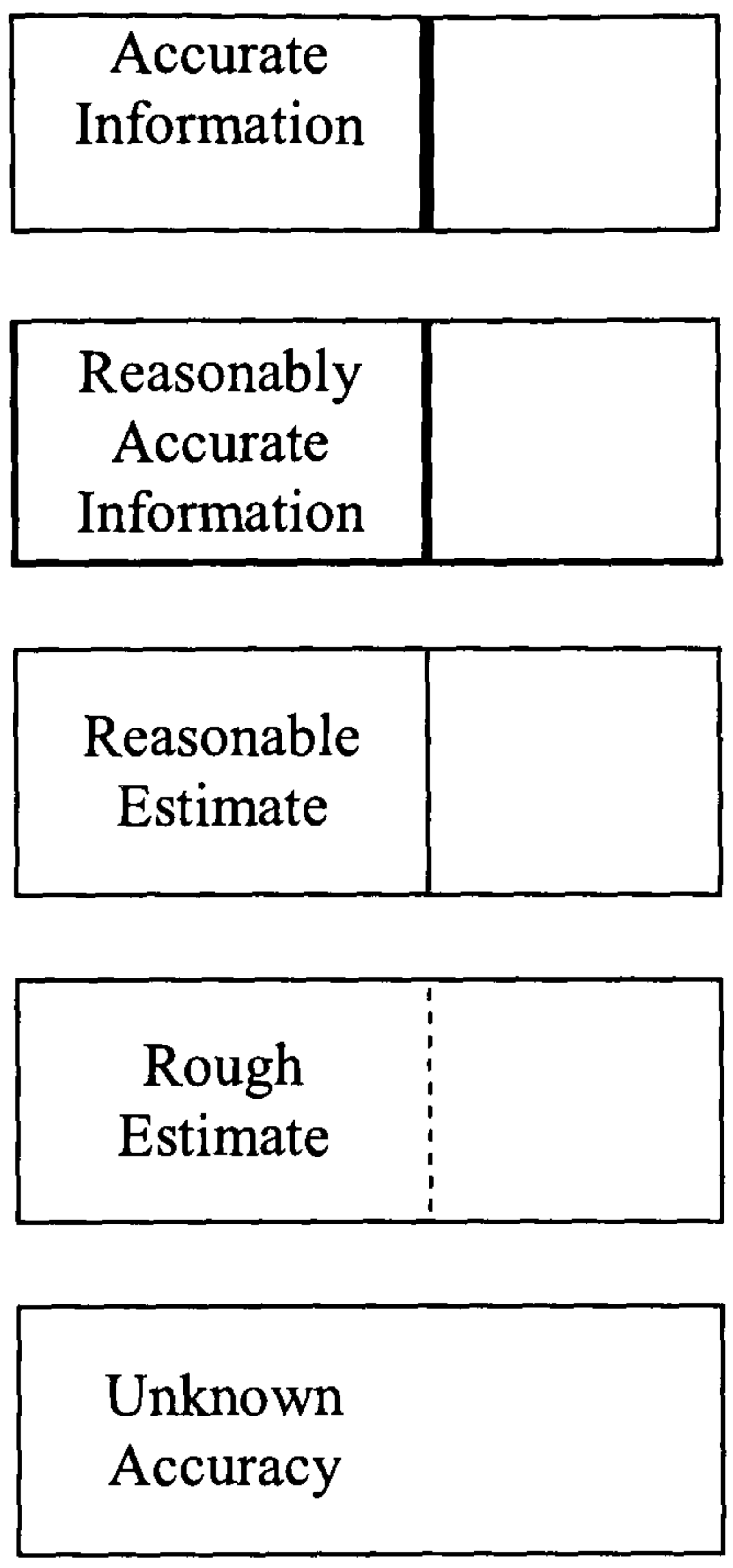
The greater use of CHP and local renewable sources in the Green and Fuel Switching Scenarios can also be expected to lead to some job creation. If these schemes were run cooperatively, they could also increase the sense of community and boost the local rural economy.

The Fuel Switching, Local Agenda 21 and Green Scenarios benefit from a diversity of sources of electricity and less reliance on oil, giving greater security of supply than experienced under the Current Trends Continued or Technical Fix Scenarios.

Energy efficiency measures, implemented in the Technical Fix, Local Agenda 21 and Green Scenarios, can help improve comfort levels in buildings by reducing heat loss through improved building insulation and can reduce 'sick building syndrome' through increased use of natural lighting and ventilation.

KEY TO TABLES 7.10-7.14

Accuracy of Information



Probability of Impact Occurring

P(H) - High Risk, >60%

P(E) - Even Risk, 40-60%

P(L) - Low Risk, >40%

P(?) - Risk Unknown

P(75) - 75% probability of impact occurring

Impact Duration

C - Commissioning

P - Project

D - Decommissioning

M - Manufacturing

A - Impact continues beyond the life of the project

Table 7.10: Summary of Impacts of the Current Trends Continued (1995 base) Scenario, 1990-2025

		Impacts of Energy EfficiencyMeasures		Impacts from Fossil and Nuclear Fuels		Impacts of Renewables	
Total Energy Consumption	**Electricity**			114 PJ from National Grid		Nil	
	Gas			309 PJ Natural Gas			
	Oil			137 PJ			
	Solid Fuel			5.5 PJ			
	Total			565 PJ		Nil	
1. Capital Cost	**£(1990) millions**	£106 to £1,147	C, P(H), Businesses and Households	Included in Fuel Costs			
2. O&M Costs	**a. Fuel Costs**	Negligible		£3505 to £3990 million?	O, P(H), Households, Businesses in Council Area		
	b. Other O&M Costs	Negligible		Included in Fuel Costs			
3. Land Use, Landscape and Open Land				Possible use of agriculture land and/or wilderness areas for:			
				a) Coal production	COD, P(H), Tourists, Rural Communities;		
				b) Siting of new power stations	COD, P(E), Local Residents		
				c) New power lines	CD, P(L), Tourists, Local Communities		
4. Noise				Explosive noise from Oil surveying,	C, P(L), Costal Settlements,		
				Significant noise from coal mining and preparation	COD, P(H), Tourists, Rural Communities		

		Impacts of Energy Efficiency Measures		Impacts from Fossil and Nuclear Fuels		Impacts of Renewables	
5. Visual Intrusion				Oil and Gas rigs visible from shoreline,	COD, P(L), Tourists, Costal Settlements,		
				Scarred landscape from coal mining,	COD, P(H), Tourists, Rural Communities,		
				Transmission Pylons,	COD, P(?), Tourists, Rural Communities,		
				Power Plants	COD, P(H), Tourists, Rural Communities		
6. Transport	**a. Power Transmission**			Power Plants often need to be located near significant sources of water - power lines needed	COD, P(?), Residents along route		
	b. Other Transport			Increased road transport to transport coal and oil	COD, P(H), Tourists, Rural Communities		
7. Health and Safety	**a. Hazardous Materials**						
	b. Ionising Radiation			Low rates from radio-active sourced nuclear tools used in oil and gas production, Risk of leaks from Nuclear plants	CODA, P(?), Workers; ODA, P(L), depends on size of accident/leak - Workers, Local Communities to Continental.		
	c. Other Risks	reduction of sick building syndrome	O, P(?), Business es, Workers	Risks from dust, particulates, noise, methane explosions, tunnel collapse from coal mining and preparation	COD, P(H), Workers		

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
8. Ecology				Disturbance from large projects on Greenfield sites, marine life disturbed by seismic oil surveys, clearance of land to construct pylons	COD, P(H), -; C, P(L), Fishermen; COD, P(E), Tourism, Rural Communities.		
9. Job Creation/Loss							
10. Liveability of Urban and Rural Areas	**a. Security**			Cost of providing extra security over and above that supplied by the plant owners	ODA, P(?), Nat. Gov.		
	b. Electro-magnetic Interference						
	c. Recreation			Surface subsidence, changes to familiar scenery. Some impact on comfort and amenity	ODA, P(H), Tourists, Rural Communities		
	d. Odours and Smells						
	e. Building Quality	Increased levels of comfort, increased levels of lighting	O, P(H), Employees and Households				
11. Water Conservation and Quality	**a. Water Usage**						
	b. Water Quality			225 tonnes of oil spilt due to oil production, 5965 tonnes discharged on drill cuttings and 4850 tonnes with produced water. Current regs limit oil content of water to 40ppm, also pipeline leaks	CODA, P(H), -		

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
11. Water Conservation and Quality continued...	**c. Groundwater**			Potential contamination from organic compounds and metals released during coal gasification. Soluble salts and phenolic compounds in the ash and char remains	CODA, P(?), -		
	d. Drainage Patterns			Changes to water drainage patterns due to subsidence leading to changes in both surface topography and underlying strata	CODA, P(?), -		
12. Resources	**a. Natural Resources**			Depletion of Oil, Gas, Coal and Uranium Reserves	OA, P(100), -		
	b. Infrastructure/ Man-made Resources			Cost to the government and/or local authority of providing additional infrastructure when new power plants are built varies depending on local circumstances	COA, P(H), Nation and/or Local Communiti es		

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
13. Greenhouse Gas Emissions	**a. Carbon Dioxide**	Used as blowing agent for some foamed plastic insulation materials. Some releases during production	M, P(H), -	37 million tonnes + emissions from gas flaring, leakages, and gas used as part of the oil production process	COA, P(H), -		
	b. Nitrogen Oxides			68 million tonnes + emissions from gas flaring, leakages, and gas used as part of the oil production process	COA, P(H), -		
	c. Methane			4000 tonnes+ small amounts from gas flaring, leakages, and gas used as part of the oil production process	COA, P(H), -		
	d. CFCs	CFCs used as blowing agents in the production of some foamed plastic insulation materials. HFCs and CO2 also used.	M, P(H), -				
14. Air Quality	**a. Sulphur Dioxide**			112 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 95 thousand tonnes Locally	COA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
14. Air Quality continued ...	**b. Nitrogen Oxides**			34 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 33 thousand tonnes locally	COA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	c. Carbon Monoxide			14.7 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 3.7 thousand tonnes locally	COA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	d. VOC			2.2 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 1.6 thousand tonnes locally	COA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	e. Particulates			Airborne dust can be combated, 0.02% of coal lost during transport loading, coal dust from rail transport, 6.4 tonnes nationally, 2.8 tonnes locally from burning fossil fuels	COA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	f. Thermal Emissions			Some but low	COD, P(L), Local Communities		
	g. Other Emissions			Potential leakage of 300gms/GJ H2 and H2S	COD, P(?), Local Communities		

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
15. Land and Soil Quality	**a. Heavy Metals**			6 to 9 g/GJ from coal preparation processes	O, P(H), Workers, Local Communities, Wider		
	b. Soil			Opencast mining - severe soil disturbance, reduces soil fertility, problems of compaction	CODA, P(H), Local Communities		
	c. Solid and Liquid Waste			Oil mud spills from drilling, spoils from coal mining and preparation, radio-active material from nuclear power plants	CO, P(H), -; CO, P(H), Local Communities; CODA, P(H), Local Communities		
	d. Other Pollutants						

Table 7.11: Summary of Impacts of the Fuel Switching Scenario, 1990-2025

		Energy Efficiency		**Fossil Fuels and Nuclear Fuels**		**Renewables**	
Total Energy Consumption	**Electricity**			182 PJ from National Grid		22.6 PJ	
	Gas			308 PJ Natural Gas			
	Oil			132 PJ			
	Solid Fuel			4.6 PJ		0.97 PJ	
	Total			625 PJ		24 PJ	
1. Capital Cost	**£(1990) millions**	£131 to £1262	C, P(H), Businesses and Households	Included in Fuel Costs		Included in Fuel Costs	
2. O&M Costs	**a. Fuel Costs**	Negligible		£3930 to £4562 (a)	O, P(H), Households, Businesses in Council Area	Included in (a)	
	b. Other O&M Costs	Negligible		Included in Fuel Costs	.	Included in Fuel Costs	
3. Land Use, Landscape and Open Land				Possible use of agriculture land and/or wilderness areas for Coal Production, and/or siting of new power stations, and power lines	COD, P(H), Tourists, Rural Communities; COD, P(E), Local Residents; CD, P(L). Tourists, Local Communities	0.15 km2 for wind turbine foundations and access roads, 100,000 m2 roof space, 10 small engine houses,	COD, P(H), Rural Communities inside and/or outside Council Area,
4. Noise				Explosive noise from Oil surveying, Significant noise from coal mining and preparation	C, P(L), Costal Settlements COD, P(H), Tourists, Rural Communities	Careful siting of wind turbines needed, some but minimal noise from extra traffic and engines	COD, P(H), Rural Communities inside and/or outside Council Area,
5. Visual Intrusion				Oil and Gas rigs visible from shoreline, Scarred landscape from coal mining, Transmission Pylons, Power Plants	COD, P(L), Tourists, Costal Settlements, COD, P(H), Tourists, Rural Communities, COD, P(?), Tourists, Rural Communities, COD, P(H), Tourists, Rural Communities	Some can be minimised with careful siting, and education programme	COD, P(?), Residents near sites

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
6. Transport	**a. Power Transmission**			Power Plants often need to be located near significant sources of water - power lines needed	COD, P(?), Residents along route	Grid lines needed from wind turbine sites to city	O, P(?), Rural Communities; Tourists outside Council Area
	b. Other Transport			Increased road transport to transport coal and oil	COD, P(H), Tourists, Rural Communities	Transportation of waste to plant of forestry residue	O, P(H), Local Residents
7. Health and Safety	**a. Hazardous Materials**					Manufacture of PV can involve the use of hazardous materials: dioborane, silane, silicon tetrafluoride gases, cadmium, tellurium, copper and indium	M, P(L), Manufacturing Staff
	b. Ionising Radiation			Low rates from radio-active sourced nuclear tools used in oil and gas production, Risk of leaks from Nuclear plants	CODA, P(?), Workers; PDA, P(L), depends on size of accident/leak - Workers, Local Communities to Continental		
	c. Other Risks	Reduction of sick building syndrome	O, P(?), Businesses, Workers	Risks from dust, particulates, noise, methane explosions, tunnel collapse from coal mining and preparation	COD, P(H), Workers	Fire risk from stored dry straw. Storage of wood chips can lead to spore release, which in a confined space, represents a health hazard. - Prolonged exposure can lead to Farmer's lung. Controlled by wearing facemasks.	O, P(L), Rural Communities inside and/or outside Council Area, O, P(L), Project Workers

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
8. Ecology				Disturbance from large projects on Greenfield sites, marine life disturbed by seismic oil surveys, clearance of land to construct pylons	COD, P(H), -; C, P(L), Fishermen; COD, P(E), Tourism, Rural Communities.	V. little damage with careful siting of projects, slight influence on micro-climate around wind turbines.	O, P(L), -;
9. Job Creation/Loss						Employment of local labour force in construction and maintenance	COD, P(?), Rural Communities and Local Communities
10. Liveability of Urban and Rural Areas	**a. Security**			Cost of providing extra security over and above that supplied by the plant owners	PDA, P(?), Nat. Gov.	Income for rural economies, security of supply, cost of energy not vulnerable to fluctuations as determined by capital costs, more jobs, less reliance on imports esp. if use UK products, Nat. Gov. looses tax revenue	COD, P(?), Rural Communities near site; O, P(L), Residents, O, P(L), Nation
	b. Electro-magnetic Interference					Not usually a problem, similar to that of static buildings	O, P(L), Rural Communities near site
	c. Recreation			Surface subsidence, changes to familiar scenery. Some impact on comfort and amenity	PDA, P(H), Tourists, Rural Communities		
	d. Odours and Smells					Specialist waste combustion can emit unpleasant odours - but can be minimised	O, P(E), Local Residents
	e. Building Quality	Increased levels of comfort, increased levels of lighting	O, P(H), Employees and Households				

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
11. Water Conservation and Quality	**a. Water Usage**					Some but low - CHP engine cooling water make up, some evaporation from hydro reservoirs	O, P(H), -
	b. Water Quality			Nationally 225 tonnes of oil spilt due to oil production, 5965 tonnes discharged on drill cuttings and 4850 tonnes with produced water. Current regs limit oil content of water to 40ppm, also pipeline leaks	CODA, P(H), -	Oxygenation of water, act as a monitoring point for pollutants, removal of debris	CO, P(E), -
	c. Ground-water			Potential contamination from organic compounds and metals released during coal gasification. Soluble salts and phenolic compounds in the ash and char remains	CODA, P(?), -	A dam or weir may cause changes in ground water levels due to seepage which can be up to 5% of the volume of the reservoir	O, P(H), -
	d. Drainage Patterns			Changes to water drainage patterns due to subsidence leading to changes in both surface topography & underlying strata	CODA, P(?), -		
12. Resources	**a. Natural Resources**			Depletion of Oil, Gas, Coal and Uranium Reserves	PA, P(100), -		
	b. Infrastructure/ Man-made Resources			Cost to the government and/or local authority of providing additional infrastructure when new power plants are built varies depending on local circumstances	CPA, P(H), Nation and/or Local Communities		

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
13. Greenhouse Gas Emissions	**a. Carbon Dioxide**	Used as blowing agent for some foamed plastic insulation materials. Some releases during production	M, P(H), -	40 million tonnes + emissions from gas flaring, leakages, and gas used as part of the oil production process	CPA, P(H), -		
	b. Nitrogen Oxides			70 million tonnes + emissions from gas flaring, leakages, and gas used as part of the oil production process	CPA, P(H), -		
	c. Methane			4100 tonnes+ small amounts from gas flaring, leakages, and gas used as part of the oil production process	CPA, P(H), -		
	d. CFCs	CFCs used as blowing agents in the production of some foamed plastic insulation materials. HFCs and CO2 also used.	M, P(H), -				

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
14. Air Quality	**a. Sulphur Dioxide**			105 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 90 thousand tonnes locally	CPA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	b. Nitrogen Oxides			33 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 37 thousand tonnes locally	CPA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	c. Carbon Monoxide			13.9 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 4 thousand tonnes locally	CPA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	d. VOC			2.1 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 2 thousand tonnes locally	CPA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	e. Particulates			Airborne dust can be combated, 0.02% of coal lost during transport loading, coal dust from rail transport, 6.1 tonnes nationally, 2.7 tonnes locally from burning fossil fuels	CPA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	f. Thermal Emissions			Some but low	COD, P(L), Local Communities	Some but majority used to produce hot water	O, P(H), Residents near site
	g. Other Emissions			Potential leakage of 4.4 thousand tonnes of H2 and H2S	COD, P(?), Local Communities	Low levels of dioxins, some acidic gases from burning waste.	O, P(H), Residents near site

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
15. Land and Soil Quality	**a. Heavy Metals**			27 to 41 tonnes from coal preparation processes	O, P(H), Workers, Local Communities, Wider	Trace from waste and biomass, some from PV which need careful handling when decommission-ing	O, P(H), Residents near site, D, P(L), Workers
	b. Soil			Opencast mining - severe soil disturbance, reduces soil fertility, problems of compaction	CODA, P(H), Local Communities		
	c. Solid and Liquid Waste			Oil mud spills from drilling, spoils from coal mining and preparation, radio-active material from nuclear power plants	CO, P(H), -; CO, P(H), Local Communities; CODA, P(H), Local Communities		
	d. Other Pollutants					Minor amounts of oil from greasing turbines, Some pollution from manufacturing process but within industrial regulations and similar to that of other equipment manufacturing	COD, P(?), -

Table 7.12: Summary of Impacts of the Technical Fix

Scenario, 1990-2025

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
Total Energy Consumption	**Electricity**			101 PJ from National Grid		Nil	
	Gas			265 PJ Natural Gas			
	Oil			125 PJ			
	Solid Fuel			4.7 PJ			
	Total			497 PJ		Nil	
1. Capital Cost	**£(1990) millions**	£191 to £1685	C, P(H), Businesses and Households	Included in Fuel Costs			
2. O&M Costs	**a. Fuel Costs**	Negligible		£3170 to £3591	O, P(H), Households, Businesses in Council Area		
	b. Other O&M Costs	Generally thought to decrease but O&M costs for some projects do increase	O, P(E) Businesses in Council Area	Included in Fuel Costs			
3. Land Use, Landscape and Open Land				Possible use of agriculture land and/or wilderness areas for Coal Production, and/or siting of new power stations, and power lines	COD, P(H), Tourists, Rural Communities; COD, P(E), Local Residents; CD, P(L), Tourists, Local Communities		
4. Noise				Explosive noise from Oil surveying, Significant noise from coal mining and preparation	C, P(L), Costal Settlements, COD, P(H), Tourists, Rural Communities		
5. Visual Intrusion				Oil and Gas rigs visible from shoreline, Scarred landscape from coal mining, Transmission Pylons, Power Plants	COD, P(L), Tourists, Costal Settlements, COD, P(H), Tourists, Rural Communities, COD, P(?), Tourists, Rural Communities. COD, P(H), Tourists, Rural Communities		

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
6. Transport	**a. Power Transmission**			Power Plants often need to be located near significant sources of water - power lines needed	COD, P(?), Residents along route		
	b. Other Transport			Increased road transport to transport coal and oil	COD, P(H), Tourists, Rural Communities		
7. Health and Safety	**a. Hazardous Materials**						
	b. Ionising Radiation			Low rates from radio-active sourced nuclear tools used in oil and gas production, Risk of leaks from Nuclear plants	CODA, P(?), Workers; PDA, P(L), depends on size of accident/leak - Workers, Local Communities to Continental.		
	c. Other Risks	Reduction of sick building syndrome	O, P(?), Businesses, Workers	Risks from dust, particulates, noise, methane explosions, tunnel collapse from coal mining and preparation	COD, P(H), Workers		
8. Ecology				Disturbance from large projects on greenfield sites, marine life disturbed by seismic oil surveys, clearance of land to construct pylons	COD, P(H), -; C, P(L), Fishermen; COD, P(E), Tourism, Rural Communities.		
9. Job Creation/Loss							

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
10. Liveability of Urban and Rural Areas	**a. Security**			Cost of providing extra security over and above that supplied by the plant owners	PDA, P(?), Nat. Gov.		
	b. Electro-magnetic Interference						
	c. Recreation			Surface subsidence, changes to familiar scenery. Some impact on comfort and amenity	PDA, P(H), Tourists, Rural Communities		
	d. Odours and Smells						
	e. Building Quality	Increased levels of comfort, increased levels of lighting	O, P(H), Employees and Households				
11. Water Conservation and Quality	**a. Water Usage**						
	b. Water Quality			225 tonnes of oil spilt due to oil production, 5965 tonnes discharged on drill cuttings and 4850 tonnes with produced water. Current regs limit oil content of water to 40ppm, also pipeline leaks	CODA, P(H), -		
	c. Groundwater			Potential contamination from organic compounds and metals released during coal gasification. Soluble salts and phenolic compounds in the ash and char remains	CODA, P(?), -		
	d. Drainage Patterns			Changes to water drainage patterns due to subsidence leading to changes in both surface topography & underlying strata	CODA, P(?), -		

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
12. Resources	**a. Natural Resources**			Depletion of Oil, Gas, Coal and Uranium Reserves	PA, P(100), -		
	b. Infrastructure/ Man-made Resources			Cost to the government and/or local authority of providing additional infrastructure when new power plants are built varies depending on local circumstances	CPA, P(H), Nation and/or Local Communities		
13. Greenhouse Gas Emissions	**a. Carbon Dioxide**	Used as blowing agent for some foamed plastic insulation materials. Some releases during production	M, P(H), -	39 million tonnes + emissions from gas flaring, leakages, and gas used as part of the oil production process	CPA, P(H), -		
	b. Nitrogen Oxides			71 million tonnes + emissions from gas flaring, leakages, and gas used as part of the oil production process	CPA, P(H), -		
	c. Methane			4200 tonnes+ small amounts from gas flaring, leakages, and gas used as part of the oil production process	CPA, P(H), -		
	d. CFCs	CFCs used as blowing agents in the production of some foamed plastic insulation materials. HFCs and CO2 also used.	M, P(H), -				

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
14. Air Quality	**a. Sulphur Dioxide**			120 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 86 thousand tonnes locally	CPA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	b. Nitrogen Oxides			37 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 34 thousand tonnes locally	CPA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	c. Carbon Monoxide			15.8 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 3.7 thousand tonnes locally	CPA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	d. VOC			2.4 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 1.8 thousand tonnes locally	CPA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	e. Particulates			Airborne dust can be combated, 0.02% of coal lost during transport loading, coal dust from rail transport, 6.9 tonnes nationally, 2.5 tonnes locally from burning fossil fuels	CPA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	f. Thermal Emissions			Some but low	COD, P(L), Local Communities		
	g. Other Emissions			Potential leakage of 1400 tonnes of H2 and H2S	COD, P(?), Local Communities		

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
15. Land and Soil Quality	**a. Heavy Metals**			28 to 42 tonnes from coal preparation processes	O, P(H), Workers, Local Communities, Wider		
	b. Soil			Opencast mining - severe soil disturbance, reduces soil fertility, problems of compaction	CODA, P(H), Local Communities		
	c. Solid and Liquid Waste			Oil mud spills from drilling, spoils from coal mining and preparation, radio-active material from nuclear power plants	CO, P(H), -; CO, P(H), Local Communities; CODA, P(H), Local Communities		
	d. Other Pollutants						

Table 7.13: Summary of Impacts of the Local Agenda 21 Scenario, 1990-2025

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
Total Energy Consumption	**Electricity**			103 PJ from National Grid		0.84 PJ	
	Gas			277 PJ Natural Gas			
	Oil			104 PJ			
	Solid Fuel			5.8 PJ		1.4 PJ	
	Total			489 PJ		2.2 PJ	
1. Capital Cost	**£(1990) millions**	£204 to £1500	C, P(H), Businesses and Households	Included in Fuel Costs		Included in Fuel Costs	
2. O&M Costs	**a. Fuel Costs**	Negligible		£3077 to £3472 (a)	O, P(H), Households, Businesses in Council Area	Included in (a)	
	b. Other O&M Costs	Increased Maintenance costs for some measures, decreased for others		Included in Fuel Costs		Included in Fuel Costs	
3. Land Use, Landscape and Open Land				Possible use of agriculture land and/or wilderness areas for Coal Production, Possible use of agriculture land and/or wilderness areas for siting of new power stations, Possible use of agriculture land and/or wilderness areas for power lines	COD, P(H), Tourists, Rural Communities, COD, P(E), Local Residents, CD, P(L), Tourists, Local Communities	0.02 km2 for wind turbine foundations and access roads, 10,000 m2 roof space, 5 small engine houses	COD, P(H), Rural Communities inside and/or outside Council Area, COD, P(L), Rural Communities
4. Noise				Explosive noise from Oil surveying, Significant noise from coal mining and preparation	C, P(L), Costal Settlements, COD, P(H), Tourists, Rural Communities	Careful siting of turbines needed, some but minimal noise from extra traffic and engines	COD, P(H), Rural Communities inside and/or outside Council Area.

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
5. Visual Intrusion				Oil and Gas rigs visible from shoreline, Scarred landscape from coal mining, Transmission Pylons, Power Plants	COD, P(L), Tourists, Costal Settlements, COD, P(H), Tourists, Rural Communities, COD, P(?), Tourists, Rural Communities, COD, P(H), Tourists, Rural Communities	Some can be minimised with careful siting, and education programme	COD, P(?), Residents near sites
6. Transport	**a. Power Transmission**			Power Plants often need to be located near significant sources of water - power lines needed	COD, P(?), Residents along route	Grid lines needed from wind turbine sites to city	O, P(?), Rural Communities, Tourists outside Council Area
	b. Other Transport			Increased road transport to transport coal and oil	COD, P(H), Tourists, Rural Communities	Transportation of waste to plant of forestry residue	O, P(H), Local Residents
7. Health and Safety	**a. Hazardous Materials**					Manufacture of PV can involve the use of hazardous materials: dioborane, silane, silicon tetrafluoride gases, cadmium, tellurium, copper and indium	M, P(L), Manufacturing Staff
	b. Ionising Radiation			Low rates from radio-active sourced nuclear tools used in oil and gas production, Risk of leaks from Nuclear plants	CODA, P(?), Workers; PDA, P(L), depends on size of accident/leak - Workers, Local Communities to Continental.		

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
7. Health and Safety continued...	**c. Other Risks**	Reduction of sick building syndrome	O, P(?), Businesses, Workers	Risks from dust, particulates, noise, methane explosions, tunnel collapse from coal mining and preparation	COD, P(H), Workers	Fire risk from stored dry straw Storage of wood chips can lead to spore release, which in a confined space, represents a health hazard. - Prolonged exposure can lead to Farmer's lung. Controlled by wearing face masks..	O, P(L), Rural Communities inside and/or outside Council Area O, P(L), Project Workers,
8. Ecology				Disturbance from large projects on greenfield sites, Marine life disturbed by seismic oil surveys, Clearance of land to construct pylons	COD, P(H), -; C, P(L), Fishermen; COD, P(E), Tourism, Rural Communities .	V. little damage with careful siting of projects, slight influence on micro-climate below and behind wind turbines	O, P(L), -
9. Job Creation/Loss						Employment of local labour force in construction and maintenance	COD, P(?), Rural Communities and Local Communities
10. Liveability of Urban and Rural Areas	**a. Security**			Cost of providing extra security over and above that supplied by the plant owners	PDA, P(?), Nat. Gov.	Income for rural economies, Security of supply, cost of energy not vulnerable to fluctuations as determined by capital costs, more jobs, Less reliance on imports esp. if use UK products, Nat. Gov. loses tax revenue	COD, P(?), Rural Communities near site; O, P(L), Residents; O, P(L), Nation
	b. Electro-magnetic Interference					Not usually a problem, similar to that of static buildings	O, P(L), Rural Communities near site
	c. Recreation			Surface subsidence, changes to familiar scenery. Some impact on comfort and amenity	PDA, P(H), Tourists, Rural Communities		

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
10. Liveability of Urban and Rural Areas continued...	**d. Odours and Smells**					Specialist waste combustion can emit unpleasant odours - but can be minimised	O, P(E), Local Residents
	e. Building Quality	Increased levels of comfort, increased levels of lighting	O, P(H), Employees and Households				
11. Water Conservation and Quality	**a. Water Usage**					Some but low - CHP engine cooling water make up	O, P(H), -
	b. Water Quality			Nationally 225 tonnes of oil spilt due to oil production, 5965 tonnes discharged on drill cuttings and 4850 tonnes with produced water. Current regs limit oil content of water to 40ppm, also pipeline leaks	CODA, P(H), -		
	c. Groundwater			Potential contamination from organic compounds and metals released during coal gasification. Soluble salts and phenolic compounds in the ash and char remains	CODA, P(?), -		
	d. Drainage Patterns			Changes to water drainage patterns due to subsidence leading to changes in both surface topography and underlying strata	CODA, P(?), -		

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
12. Resources	**a. Natural Resources**			Depletion of Oil, Gas, Coal and Uranium Reserves	PA, P(100), -		
	b. Infrastructure/ Man-made Resources			Cost to the government and/or local authority of providing additional infrastructure when new power plants are built varies depending on local circumstances	CPA, P(H), Nation and/or Local Communities		
13. Greenhouse Gas Emissions	**a. Carbon Dioxide**	Used as blowing agent for some foamed plastic insulation materials. Some releases during production	M, P(H), -	39 million tonnes + emissions from gas flaring, leakages, and gas used as part of the oil production process	CPA, P(H), -		
	b. Nitrogen Oxides			70 million tonnes + emissions from gas flaring, leakages, and gas used as part of the oil production process	CPA, P(H), -		
	c. Methane			4300 tonnes+ small amounts from gas flaring, leakages, and gas used as part of the oil production process	CPA, P(H), -		
	d. CFCs	CFCs used as blowing agents in the production of some foamed plastic insulation materials. HFCs and CO2 also used.	M, P(H), -				

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
14. Air Quality	**a. Sulphur Dioxide**			124 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process, 73 thousand tonnes Locally	CPA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	b. Nitrogen Oxides			38 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process 32 thousand tonnes locally	CPA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	c. Carbon Monoxide			16 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process 3.6 thousand tonnes locally	CPA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	d. VOC			2.5 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process, 1.8 thousand tonnes locally	CPA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	e. Particulates			Airborne dust can be combated, 0.02% of coal lost during transport loading, coal dust from rail transport, 7.1 tonnes nationally, 2.2 tonnes locally from burning fossil fuels	CPA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	f. Thermal Emissions			Some but low	COD, P(L), Local Communities	Some but majority used to produce hot water	O, P(H), Residents near site
	g. Other Emissions			Potential leakage of 1.7 thousand tonnes of H2 and H2S	COD, P(?), Local Communities	Low levels of dioxins, some acidic gases from burning waste.	O, P(H), Residents near site

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
15. Land and Soil Quality	**a. Heavy Metals**			36 to 52 tonnes from coal preparation processes	O, P(H), Workers, Local Communities, Wider	Trace from waste and biomass, Some from PV which need careful handling when decommissi on-ing	O, P(H), Residents near site, D, P(L), Workers
	b. Soil			Opencast mining - severe soil disturbance, reduces soil fertility, problems of compaction	CODA, P(H), Local Communities		
	c. Solid and Liquid Waste			Oil mud spills from drilling, Spoils from coal mining and preparation, Radio-active material from nuclear power plants	CO, P(H), -; CO, P(H), Local Communities; CODA, P(H), Local Communities		
	d. Other Pollutants					Minor amounts of oil from greasing turbines, Some pollution from manufacturi ng process but within industrial regulations and similar to that of other equipment manufacturi ng	COD, P(?), -

Table 7.14: Summary of Impacts of the Green Scenario,

1990-2025

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
Total Energy Consumption	**Electricity**			74 PJ from National Grid		14.6 PJ	
	Gas			217 PJ Natural Gas			
	Oil			84 PJ			
	Solid Fuel			3.9 PJ		1.7 PJ	
	Total			378 PJ		16.3 PJ	
1. Capital Cost	**£(1990) millions**	£396 to £4922	C, P(H), Businesses and Households	Included in Fuel Costs		Included in Fuel Costs	
2. O&M Costs	**a. Fuel Costs**	Negligible		£2418 to £2729 (a)	O, P(H), Households, Businesses in Council Area	Included in (a)	
	b. Other O&M Costs	Increased Maintenance costs for some measures, decreased for others		Included in Fuel Costs		Included in Fuel Costs	
3. Land Use, Landscape and Open Land				Possible use of agriculture land and/or wilderness areas for Coal Production, and/or siting of new power stations, and power lines	COD, P(H), Tourists, Rural Communities; COD, P(E), Local Residents; CD, P(L), Tourists, Local Communities	0.04 km2 for wind turbine foundations and access roads, 250,000 m2 roof space, 30 small engine houses	COD, P(H), Rural Communities inside and/or outside Council Area
4. Noise				Explosive noise from Oil surveying, Significant noise from coal mining and preparation	C, P(L), Costal Settlements, COD, P(H), Tourists, Rural Communities	Careful siting of turbines needed, some but minimal noise from extra traffic and engines	COD, P(H), Rural Communities inside and/or outside Council Area,
5. Visual Intrusion				Oil and Gas rigs visible from shoreline, Scarred landscape from coal mining, Transmission Pylons, Power Plants	COD, P(L), Tourists, Costal Settlements, COD, P(H), Tourists, Rural Communities, COD, P(?), Tourists, Rural Communities, COD, P(H), Tourists, Rural Communities	Some can be minimised with careful siting, and education programme	COD, P(?), Residents near sites

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
6. Transport	**a. Power Transmission**			Power Plants often need to be located near significant sources of water - power lines needed	COD, P(?), Residents along route	Grid lines needed from wind turbine sites to city	O, P(?), Rural Communities, Tourists outside Council Area
	b. Other Transport			Increased road transport to transport coal and oil	COD, P(H), Tourists, Rural Communities	Transportation of waste to plant of forestry residue	O, P(H), Local Residents
7. Health and Safety	**a. Hazardous Materials**					Manufacture of PV can involve the use of hazardous materials: dioborane, silane, silicon tetraflouride gases, cadmium, tellurium, copper and indium	M, P(L), Manufacturing Staff
	b. Ionising Radiation			Low rates from radio-active sourced nuclear tools used in oil and gas production, Risk of leaks from Nuclear plants	CODA, P(?), Workers; PDA, P(L), depends on size of accident/leak - Workers, Local Communities to Continental.		
	c. Other Risks	Reduction of sick building syndrome	O, P(?), Businesses, Workers	Risks from dust, particulates, noise, methane explosions, tunnel collapse from coal mining and preparation	COD, P(H), Workers	Fire risk from stored dry straw. Storage of wood chips can lead to spore release, which in a confined space, represents a health hazard. - Prolonged exposure can lead to Farmer's lung. Controlled by wearing face masks.	O, P(L), Rural Communities inside and/or outside Council Area, O, P(L), Project Workers

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
8. Ecology				Disturbance from large projects on greenfield sites, marine life disturbed by seismic oil surveys, clearance of land to construct pylons	COD, P(H), -; C, P(L), Fishermen; COD, P(E), Tourism, Rural Communities.	V. little damage with careful siting of projects, slight influence on micro-climate below and behind wind turbines	O, P(L), -
9. Job Creation/Loss						Employment of local labour force in construction and maintenance	COD, P(?), Rural Communities and Local Communities
10. Liveability of Urban and Rural Areas	**a. Security**			Cost of providing extra security over and above that supplied by the plant owners	PDA, P(?), Nat. Gov.	Income for rural economies, security of supply, cost of energy not vulnerable to fluctuations as determined by capital costs, more jobs, less reliance on imports esp. if use UK products, Nat. Gov. looses tax revenue	COD, P(?), Rural Communities near site; O, P(L), Residents, O, P(L), Nation
	b. Electro-magnetic Interference					Not usually a problem, similar to that of static buildings	O, P(L), Rural Communities near site
	c. Recreation			Surface subsidence, changes to familiar scenery. Some impact on comfort and amenity	PDA, P(H), Tourists, Rural Communities		
	d. Odours and Smells					Specialist waste combustion can emit unpleasant odours - but can be minimised	O, P(E), Local Residents
	e. Building Quality	Increased levels of comfort, increased levels of Natural lighting	O, P(H), Employees and House holds				

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
11. Water Conservation and Quality	**a. Water Usage**					Some but low - CHP engine cooling water make up	O, P(H), -
	b. Water Quality			Nationally 225 tonnes of oil spilt due to oil production, 5965 tonnes discharged on drill cuttings and 4850 tonnes with produced water. Current regs. limit oil content of water to 40ppm, also pipeline leaks	CODA, P(H), -		
	c. Groundwater			Potential contamination from organic compounds and metals released during coal gasification. Soluble salts and phenolic compounds in the ash and char remains	CODA, P(?), -		
	d. Drainage Patterns			Changes to water drainage patterns due to subsidence leading to changes in both surface topography and underlying strata	CODA, P(?), -		
12. Resources	**a. Natural Resources**			Depletion of Oil, Gas, Coal and Uranium Reserves	PA, P(100), -		
	b. Infrastructure/ Man-made Resources			Cost to the government and/or local authority of providing additional infrastructure when new power plants are built varies depending on local circumstances	CPA, P(H), Nation and/or Local Communities		

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
13. Greenhouse Gas Emissions	**a. Carbon Dioxide**	Used as blowing agent for some foamed plastic insulation materials. Some releases during production	M, P(H), -	29 million tonnes + emissions from gas flaring, leakages, and gas used as part of the oil production process	CPA, P(H), -		
	b. Nitrogen Oxides			53 million tonnes + emissions from gas flaring, leakages, and gas used as part of the oil production process	CPA, P(H), -		
	c. Methane			3200 tonnes+ small amounts from gas flaring, leakages, and gas used as part of the oil production process	CPA, P(H), -		
	d. CFCs	CFCs used as blowing agents in the production of some foamed plastic insulation materials. HFCs and CO2 also used.	M, P(H), -				
14. Air Quality	**a. Sulphur Dioxide**			92 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 58 thousand tonnes locally	CPA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	b. Nitrogen Oxides			28 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 25 thousand tonnes locally	CPA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	c. Carbon Monoxide			12 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 2.7 thousand tonnes locally	CPA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
14. Air Quality continued ...	**d. VOC**			1.8 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 1.4 thousand tonnes locally	CPA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	e. Particulates			Airborne dust can be combated, 0.02% of coal lost during transport loading, coal dust from rail transport, 5.3 tonnes nationally, 1.7 tonnes locally from burning fossil fuels	CPA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	f. Thermal Emissions			Some but low	COD, P(L), Local Communities	Some but majority used to produce hot water	O, P(H), Residents near site
	g. Other Emissions			Potential leakage of 1.2 thousand tonnes of H2 and H2S	COD, P(?), Local Communities	Low levels of dioxins, some acidic gases from burning waste.	O, P(H), Residents near site
15. Land and Soil Quality	**a. Heavy Metals**			23 to 35 tonnes from coal preparation processes	O, P(H), Workers, Local Communities, Wider	Trace from waste and biomass, some from PV needs handling carefully when decommissioning	O, P(H), Residents near site, D, P(L), Workers
	b. Soil			Opencast mining - severe soil disturbance, reduces soil fertility, problems of compaction	CODA, P(H), Local Communities		
	c. Solid and Liquid Waste			Oil mud spills from drilling, spoils from coal mining and preparation, radio-active material from nuclear power plants	CO, P(H), -; CO, P(H), Local Communities; CODA, P(H), Local Communities		
	d. Other Pollutants					Minor amounts of oil from greasing turbines, Some pollution from manufacturing process but within industrial regulations and similar to that of other equipment manufacturing	COD, P(?), -

7.4 Analysis of the Results

The Fuel Switching Scenario evaluation showed clearly how a mixture of policies each aimed at different objectives, such as reducing energy consumption, improving local air quality and reducing energy-related greenhouse gas emissions, can lead to conflict and produce a scenario which achieves few of the objectives efficiently and completely fails to achieve others. For example, as shown in Table 7.11, more delivered energy was used in the Fuel Switching Scenario than the Current Trends Continued Scenario, the emissions involved had a greater global warming potential and showed only slight reductions in local SO_2 and black smoke. Other local emissions affecting air quality rose compared with the Current Trends Continued Scenario.

The Fuel Switching Scenario did succeed in one of its objectives - to increase the number of locally-owned companies supplying fuel to the Local Authority area. However, if this objective had been defined slightly differently - i.e. to keep as much of the money spent on energy and energy products within the local economy as possible - then the scenario performance would not have been as good, as it failed to reduce the amount paid in taxes on fuel purchases to National Government compared with the Current Trends Continued Scenario.

The Technical Fix Scenario performed well when total emissions, greenhouse gas emissions and reductions in energy consumption levels were considered. In the low price case, these impact reductions were achieved with reduced monetary spending (capital and energy costs). However, as in the Green Scenario, the monetary outlay in the high prices case was greater than that for the Current Trends Continued high price case.

The Technical Fix Scenario performed less well when local emissions (i.e. those affecting local air quality) were chosen as the prime selection criterion. In this respect, the Technical Fix Scenario outperformed the Fuel Switching Scenario and the Current Trends Continued Scenario but did not perform as well as the Local Agenda 21 Scenario or the Green Scenario.

For the Local Agenda 21 Scenario, total monetary expenditure was reduced compared with Current Trends Continued Scenario, across the whole range of fuel prices and capital costs. All local emissions (except VOCs) were reduced, though not so substantially as in the Green Scenario. However, the Local Agenda 21 Scenario showed increased global warming potential compared with Current Trends Continued Scenario. This was attributed to an increase in the use of electric vehicles to improve local air quality.

The Local Agenda 21 Scenario performed well when local air quality was the prime criterion by which the scenarios were judged, giving good returns on total monetary expenditure at little risk. The total expenditure on capital equipment and energy was reduced compared with the Current Trends Continued Scenario for both high and low price cases. All local emissions were reduced (except for VOCs), though not as substantially as in the Green Scenario. However, the LA21 Scenario showed an increased level of CO_2 emissions and Greenhouse Gases (measured in terms of CO_2 equivalent global warming potential) when compared with the Current Trends Continued Scenario.

The Green Scenario in general performs well: it produced the lowest levels of emissions both nationally and locally, it had the lowest levels of energy consumption and the lowest fuel costs. However, the capital costs in this scenario were high. In the high price case for the Green Scenario no monetary savings were made. In the low price case the Green Scenario was estimated to save both money and energy, with this scenario requiring the lowest total expenditure and the lowest levels of delivered energy. The Green Scenario was also assessed as having the least environmental burden.

The Green Scenario, in the high fuel price case, produced the lowest levels of emissions, both nationally and locally, and had the lowest fuel costs. However it involved high capital costs per unit of energy saved. At the bottom end of the range of total possible monetary costs, the Green Scenario implied both energy savings and total monetary cost savings. At the top end of the range of total possible monetary costs, the Green Scenario implied additional expenditure above that implied by Current Trends Continued Scenario. This reflected the large range of possible capital costs associated with the Green Scenario.

In conclusion, the best scenario depends very much on the importance placed by the decision makers on each of the possible selection criteria. No one scenario stood out as being the obvious choice. The Green Scenario could cost a lot of money to implement, at the high end of the cost range; or, at the lower end of the range it could save Milton Keynes residents and businesses substantial amounts of monetary expenditure whilst still reducing the impacts of their energy consumption.

7.5 Discussion of the Methodology

In producing the impacts tables, two forms of colour coding were used. In the full impacts tables and in the impacts database (see Titheridge, 2004), colour coding was used to indicate the source of the information, with black text indicating information gathered from several different sources. In the summary tables (Tables 7.10 to 7.14 above), colours were used to distinguish between different types of impact under each of the general headings, rather than between different sources of information about the same impacts, as this allowed similar information from different sources to be précised and several impacts to be listed in a single cell of the appraisal matrix. This changing use of colour coding in different tables is likely to be confusing for those interpreting the appraisal tables. Colour coding the information according to source is probably unnecessary. This type of metadata is likely to be of little value to non-experts, as they are unlikely to know the literature and thus use this information to interpret the quality of the information gleaned from it. Providing the data source to enable users to assess the quality of the data is also, to some extent, a duplication of effort since the matrix is designed to show the reader the level of certainty that the information is correct – represented by the thickness of the line splitting each cell. Additionally, the use of colours did not allow for the identification of sources of information taken from multiple references. Finally, the use of colour is ineffective if the tables are then printed or photocopied in black and white, or even greyscale. Thus alternative ways of providing the source of the information and of distinguishing between different types of impact under each general heading need to be developed.

The burden of setting up the energy and emissions model and creating the scenarios based on a number of loosely-defined scenarios may be problematic for Local Authorities with limited resources and a lack of expertise in this area. The scenario creating process required a large number of assumptions to be made regarding future trends and the potential for different technologies under different policy regimes, requiring substantial knowledge of across a very wide range of technologies. From my experience in constructing these scenarios I know that keeping up to date on such a wide range of technologies is very time consuming. As a way to reduce the workload, I based many of my assumptions on scenarios developed for other areas (e.g. Leicester). I suspect that many Local Authorities would adopt a similar practice. If not done with great care, the assumptions made for one location may not be suitable for another, due to differing demographics, building types and structures in the domestic and non-domestic sectors in the two areas. In addition, due to changing political climates and unforeseen developments in new technologies, the assumptions made may be out of date.

Some detail was lost during the process of trying to summarise qualitative data in short sentences suitable for tabulation in the matrices. However, sufficient detail was maintained to be able to distinguish between the expected impacts of different scenarios. The summary tables produced are relatively easy to read and compare, whilst providing a lot of information on the likely impacts of each scenario.

7.6 Conclusions on the Methodology

Despite the loss of some detail in the appraisal process (and some misgivings about the level of resources required to undertake energy policy appraisal using this methodology), the methodology did enable the characteristics of the five test scenarios to be distinguished clearly and highlighted the fact that the choice of scenario depended on the importance placed on the different sustainability criteria. I was sufficiently confident in the robustness of the results to proceed to the next step: testing the methodology with a potential user of the appraisal process, making only a few minor adjustments to the methodology.

Chapter Eight

METHODOLOGY TESTING

8.1 INTRODUCTION

The second phase of the methodology development process was to test the usefulness of the assessment framework and appraisal methodology for energy policy makers. This was achieved by working with Milton Keynes Energy Agency to develop a number of alternative energy scenarios for the borough and to compare these strategies using the sustainability framework developed.

8.2 THE PROCESS

An initial meeting was held with Milton Keynes Energy Agency. During this meeting MKEA were given a demonstration of the energy model and the assessment framework was outlined. Discussions about the level of technical expertise required to run the energy model, computer software requirements and the timescale for the work led to the conclusion that rather than MKEA using the assessment toolkit themselves, the application of the tools to the strategies would be undertaken by the author, who would then feed the results back to MKEA. MKEA wanted to assess (i) a strategy for achieving the target of 10 percent of electricity to come from renewables by 2010, set by the UK Government as part of the national energy strategy; and (ii) a strategy for achieving zero growth in carbon dioxide emissions.

The work was due to be carried out in a number of phases.

1. Model Update. MKEA supplied much of the data required to update the model, which was originally created in 1995. It was not possible to revalidate the model using electricity and gas sales data, as what little data was provided was not of sufficient quality. Details of the 1995 validation are given in Chapter Three and in Titheridge and Boyle (1996).

2. Once the model was updated, estimates of energy supply and demand broken down by fuel and end use in 2000, 2010 and 2025 were determined on the

assumption that current trends would continue. The results from this run are referred to as Current Trends Continued (2000 base) in the text, more details of which are given in section 8.4.1 below.

3. Output from the Current Trends Continued (2000 base) scenario was fed back to MKEA. This data was used by MKEA to estimate maximum potential uptake for a variety of renewable energy technologies. Based on this data and information on renewable energy capacity levels, based in turn on economically feasible resources within Milton Keynes Council boundaries, MKEA produced a series of assumptions for each renewable energy technology to be included in their renewables strategy. These assumptions were then translated into the correct format for the Milton Keynes Energy Model. Where additional assumptions were required, for example solar photovoltaic module efficiency, suggestions were put forward. This process was repeated several times until both parties were happy with the set of assumptions.

4. The assumptions as specified by MKEA were entered into the model (see 3 above); all other parameters were kept as for Current Trends Continued (2000 base). This scenario is referred to as Renewables A. Results from the model were analysed to test whether the target (10 percent of electricity to come from renewables by 2010) was being met.

5. The renewable energy capacity included in the scenario was then adjusted. The adjusted figures were again supplied by MKEA. This took a few iterations to produce a set of suitable values. The iterations were required this time not because of a lack of understanding of the model requirements as for 3 above, but because some of the suggested values resulted in a mismatch between supply and demand within Milton Keynes. Some of these problems only became apparent when the model was rerun. The final set of values used in this scenario - Renewables B - are outlined later in this chapter.

The final stage of this process was to assess how zero CO2 growth could be achieved. The idea behind this strategy was that any new developments in Milton Keynes should have a zero carbon dioxide outcome, i.e. that no carbon dioxide emissions would be produced by the new developments for either heating buildings or industrial production purposes. There were a variety of ways in which zero carbon dioxide emissions growth could be achieved – through an investment on-site in energy efficiency and renewables or an investment elsewhere in the city on measures that would reduce the city's CO2 emissions by the equivalent of those that a new development would produce.

This was envisaged as being an iterative process, starting from a base of the Renewables B Scenario and adding energy efficiency measures until zero growth in carbon dioxide emissions was achieved. Here the aim was to see if the methodology and assessment framework could be used to determine whether a target was achievable and whether the fiscal mechanism envisaged for achieving this target (a sum payable per development as part of the planning obligations) would be capable of raising sufficient capital. However, as the resulting emissions from the Renewables B Scenario were effectively zero CO2 growth, no further modelling was required as the remit was to examine whether this goal was possible.

8.3 Model Update

The model was updated as much as possible using data for 1995 to 2000, where available. Some data were, however, unavailable: for example, MKEA were unable to supply temperature data for 1995 to 2000. The current mix of fuels for energy generation was taken from (DTI, 1998).

Information on the total number of square metres of floor area of buildings for the period 1995 to 2000 in each services sub-sector came from a variety of different sources including: Milton Keynes Borough Council, the Commission for New Towns, Buckinghamshire County Council, Milton Keynes NHS Trust, and the Open University and Dti (2000). Where data was only available on the number of buildings used for a particular purpose, a figure for total floor area was estimated using data on the typical floor area of buildings used for that sector.

Data on the population of Milton Keynes was updated using mid-year estimates from Milton Keynes Council and the latest figures on the number of students resident in Milton Keynes were obtained. In 1995, it was estimated that approximately 2000 students were resident in Milton Keynes (personal communication with De Montfort

University registrar's office, 1995). By 2000, this number had decreased to around 800 (www.dmu.ac.uk, 2000). Data on the number of dwellings constructed and the numbers demolished in the Council Area between 1995 and 2000 were obtained from the Housing Construction Statistics (CSO, 2000). The mean heat loss parameter for 2000 was calculated using the method outlined in Chapter Six.

Updated figures on the annual output and the number of business units for each industrial sub-sector was obtained from the Business Statistics Office (CSO, 2001) for 1998. It was assumed that the changes between these years for which data was available (1981, 1992 and 1998) were linear and that production continued to increase at the same rate until 2000. Seasonal variations in production were not included. Information on total industrial floor space was obtained from the Commission for New Towns. It was assumed that floor space in each of the industrial sub-sectors increased at the same rate as the number of units between 1981 and 2000. 1995 to 2000 data for the annual index of prices of industrial products was taken from the Annual Abstract of Statistics. A base of 100 in 1980 was used for consistency with previous versions of the Milton Keynes Energy Model (DREAM-MK). Where 2-figure SIC classes needed to be amalgamated to fit the sub-sectors used in the model, the classes were weighted, using output of production data for Milton Keynes, and then summed.

The Freight Transport sub-sector was updated using data on the index of monetary output for each of the sub-sectors from 1980 to 1999, taken from the Annual Abstract of Statistics (GSO, 2000). It was assumed that the index of output for each sub-sector within Milton Keynes was the same as that of the national index. The percentage of each energy source used by each mode was also taken from the same source and again it was assumed that Milton Keynes followed the national pattern. The number of tonne-kilometres per year of freight transported nationally in each of the transport sub-sectors and the percentage of these tonne-kilometres were accounted for by road, rail, water and pipeline were derived from data published in Transport Statistics (DETR, 2000). The national figures for the number of tonne-kilometres transported were adjusted for Milton Keynes using a figure based on the proportion of UK commercial floorspace (Herring, 1995) in the Council Area. As already mentioned, the number of tonne-kilometres of goods transported is assumed to increase in proportion to output – i.e.

base year * index of output/index of output in the base year. The number of tonne-kilometres of freight moved by each type of transport (road, rail, water, pipeline) is further sub-divided into the proportion transported by each fuel type before energy consumption is calculated. Historical data on this was derived from the Annual Abstract of Statistics (GSO, 2000). It was assumed that the proportions of the different types of fuel used are the same for Milton Keynes as nationally.

The personal travel sub-sector was updated using the latest data available from the National Travel Survey (DLTR, 2001) to give the number of journeys made per week for different purposes and by different modes for urban and rural areas and the average length of each journey.

Unfortunately, it was not possible to re-validate the model, as insufficient data on the more recent historical energy demand of Milton Keynes was available.

8.4 Scenario Descriptions

8.4.1 Current Trends Continued (2000 base) (CTC00)

This scenario forms the basis for all of the other scenarios tested. As its name suggests, the basic premise behind the scenario was that current trends in population growth, manufacturing and service sector growth, traffic growth, energy efficiency improvements and fuel choices continue for the next 25 years. Official statistics and government projections were used where possible. Where not, academic and technical literature was drawn upon extensively to gain an overview of what changes are likely to occur. For those very few of the model parameters on which no future trend information could be found from either government, academic or commercial sources, a crude extrapolation of previous trends was used.

Similar assumptions were used to those outlined in Chapter Five for the Current Trends Continued (1995 base). Adjustments were made where a trend had changed substantially between 1995 and 2000.

Government projections for fuel mix for electricity generation were used. These were taken from Energy Paper 68 (Dti, 2000) and assumed central economic growth projections and an average of high and low fuel price scenarios. These projections give a renewables contribution of over 10% of electricity generation in 2010 and beyond, but no details of how this total is produced are given. It was assumed that this 10% would be achieved through large-scale schemes feeding the national grid. Renewable energy schemes within the boundaries of the Milton Keynes Council area were assumed to be in addition to this 10%, although in the Current Trends Continued (2000 base) scenario the level of renewables installed within the Council area was assumed to be negligible.

8.4.1.1 Services Sector

A fairly conservative estimate of services sector floorspace growth between 2000 and 2025 was used, with floorspace assumed to grow at 1 percent per annum across all sub-sectors in line with growth rates assumed in Energy Paper 68 (DTI, 2000), giving 2025 floorspace levels very similar to those assumed for the Current Trends Continued (1995 base) scenario (see Table 8.1)

			m^2
Services Sub-Sector	**2000**	**2010**	**2025**
Offices	369,400	422,500	462,800
Shops	449,800	510,000	566,700
Distribution	335000	385,000	418,500
Commercial Services	95,100	108,800	119,200
Leisure	117,600	132,800	148,500
Residential (Hotels etc.)	37,300	42,000	47,300
Personal Services	12,700	14,500	15,900
Government	63,800	72,500	80,300
Defence	5,200	5,600	6,800
Education	281,600	325,000	351,000
Health	81,900	90,800	104,600
Catering	44,900	49,800	57,200

Table 8.1: Services Sector Floor Area by Sector for the Current Trends Continued (2000 base) Scenario, 2000-2025

8.4.1.2 Domestic Sector

Government population projections for 2001-2016 for the Unitary Authority were used. These were not significantly different from the population projections used in the Current Trends Continued (1995 base) scenario. Projections of the numbers of students resident in Milton Keynes in this scenario did, however, differ from those used previously. In 1995, it was estimated that approximately 2000 students were resident in

Milton Keynes (personal communication with De Montford University registrars office, 1995). By 2000, this number had decreased to around 800 (www.dmu.ac.uk, 2000). It was assumed that this would continue to decrease, dropping to 350 by 2010 and 250 by 2025, as more students chose to live at home due to the increasing cost of studying at university.

The number of people per household in 1980 was 2.88, falling to 2.54 by 1995. This trend was assumed to continue, resulting in a decrease to just over 2.18 people per household by 2025. The projections were derived from sub-national population trends (ONS, 1999) for the South East, East and West Midlands regions.

The number of households with solar water heating systems installed was assumed to rise from approximately 50 in 2001 to just over 1200 by 2010 and over 4500 by 2025.

8.4.1.3 Industrial Sector

For the years 2000-2025, different assumptions were made for each of the industrial sub-sectors; these assumptions were based on the national growth rates used in Energy Paper 68 (Dti, 2000) with some adjustment to reflect the historic trends of the individual sub-sectors within the Milton Keynes Council Area. The rate of change historically of output per square metre was calculated for each sub-sector and floor area growth rates were based on the assumption that these increases in productivity per square metre would continue (see Table 8.2).

			£ per m^2 floor area
Industrial		**2025**	
Sub-Sector	**2000**	**CTC95**	**CTC00**
Ceramics	0.08	0.18	0.13
Chemicals	1.47	1.91	2.17
Construction	1.08	0.55	1.62
Engineering	10.47	9.93	16.64
Food, Drink	3.65	3.22	4.83
Metals	0.99	1.63	1.29
Others	1.00	0.72	1.50
Paper	1.49	2.39	2.42
Rubber, Plastics	3.88	2.78	5.82
Textiles	0.15	0.40	0.42
Vehicles	3.01	3.20	3.15

Table 8.2: Industrial Sector Output of Production by Sub-Sector and Scenario, 2000-2025

8.4.1.4 Transport Sector

Three sectors were assumed to see an increasing proportion of their freight being transported by rail. These were machinery and miscellaneous, ores and metal wastes, and solid fuel, rising from 7%, 33% and 45% respectively in 2000 to 8%, 38.5% and 49% in 2025 (Table 8.3). Only one sector was assumed to have a decreasing proportion of its freight transported by rail: building materials, in which it decreased from 7% to 4.5% over the 25-year period. It was assumed that no foodstuffs would be transported by rail. The remaining sectors were assumed to have a relatively constant proportion of their freight being transported by rail. As the output from each of these sectors is increasing, this still results in an increasing amount of rail freight. The proportions of freight by rail for these sectors are 2% of chemicals, 10% of fertilisers, 18% of metals, 3% of petroleum products, and 2% of agricultural products.

	Mode Share *(%)*				Goods transported *(Tonne-km)*
	Road	**Rail**	**Water**	**Pipe**	
Agricultural Products					
1995	94	3	4	0	45,710
2025	95	2	3	0	61,329
Chemicals					
1995	91	5	4	0	36,007
2025	97	2	1	0	64,608
Fertilisers					
1995	85	8	8	0	8,280
2025	81	10	9	0	4,712
Foodstuffs					
1995	99	1	0	0	87,108
2025	100	0	0	0	168,769
Machines and Miscellaneous Products					
1995	85	8	7	0	162,573
2025	90	8	2	0	336,359
Metal Products					
1995	78	19	3	0	33,938
2025	81	18	1	0	42,404
Minerals and Building Materials					
1995	81	7	13	0	101,770
2025	71	5	24	0	182,772
Ores and Metal Wastes					
1995	59	41	0	0	8,280
2025	61	39	0	0	14,414
Petroleum Products					
1995	10	3	70	17	252,268
2025	7	3	70	20	168,769
Solid Fuels					
1995	35	39	27	0	52,179
2025	40	49	11	0	61,329

Table 8.3: Freight Transport – Goods Transported and Mode Share by Sub-sector for the CTC00 Scenario, 1995-2025

The transport of freight by water also showed a wide range of differing trends. Three sectors – chemicals, fertilisers and building materials were assumed to transport an increasing proportion of freight by water, rising from 1%, 6% and 20% in 2000 to 1.5%, 8.6% and 24% respectively. There was assumed to be no increase in the proportion of metals (1%), petroleum (7%) and agricultural products (3%) transported by water over the time period. There was assumed to be a decrease in the proportion of machinery and solid fuel transported by water, from 4.5% and 15% in 2000 to 2.4% and 11%

respectively in 2025. It was assumed that negligible amounts of ores and metal wastes, and foodstuff would continue to be transported by water.

Petroleum was the only product of which a significant amount was transported by pipeline in 2000. It was assumed that 20% of petroleum would continue to be transported by pipeline over the next 25 years. Road accounted for all remaining freight.

The fuel efficiencies of all modes of personal transport were assumed to improve by 25% over 2000 levels by 2025, due to the gradual replacement of vehicles by newer, more efficient ones. It was not assumed that consumers would purchase the most efficient vehicle on the market.

									Journeys per Person per Week
		Urban				**Rural**			
		Car		**No Car**		**Car**		**No Car**	
Purpose	**Mode**	**1995**	**2025**	**1995**	**2025**	**1995**	**2025**	**1995**	**2025**
Work	Car	19.81	24.04	2.26	3.00	20.65	23.55	2.68	2.29
	Bus	1.38	0.23	2.99	2.30	0.76	0.22	1.39	1.03
	Rail	0.85	1.08	0.94	0.94	0.24	0.33	0.01	0.03
Shopping	Car	33.93	37.50	6.41	8.47	34.84	40.75	7.52	8.75
	Bus	0.38	0.05	4.92	3.69	0.16	0.01	2.67	1.78
	Rail	0.18	0.03	0.67	0.38	0.08	0.02	0.43	0.22
Leisure	Car	12.25	14.90	1.86	2.85	13.26	15.40	3.26	4.23
	Bus	0.59	0.14	5.13	4.62	0.17	0.01	4.02	3.18
	Rail	0.06	0.01	0.23	0.03	0.01	0.01	0.09	0.01

Table 8.4: Mean Number of Journeys made per Person per Week for Urban and Rural Car Owning and Non-Car Owning Households by Purpose and Mode, for CTC00 Scenario, 1995-2025

Journeys by rail for work purposes was assumed to increase slightly, with people taking advantage of the fast links to London, whilst journeys by rail for shopping and leisure purposes were assumed to decrease slightly, as people take advantage of the city expansion and increased variety of leisure and shopping facilities (Table 8.4).

8.4.2 Renewables A Scenario (RENA)

The same assumptions were used for this scenario as for Current Trends Continued (2000 base) except for those given below, dealing with mainly with energy supply. A few minor adjustments were required to the fuel demand variables to match supply and demand for the various fuel types. No changes were made to any economic growth or energy efficiency variables.

8.4.2.1 Services Sector

It was assumed that 1000 photovoltaic systems would be fitted in service sector buildings by 2010, and that this would rise to 10,000 by 2025. It was assumed that the average system would have a photovoltaic array of 9 m^2, an inverter efficiency of 0.9 in 2010 (rising to 0.95 by 2025), and an array efficiency of 0.18 in 2010 (0.2 in 2025) for new systems. In effect, 1% of services sector roof space would be covered with photovoltaic systems in 2010, rising to 6% by 2025. It was assumed that a further 50 buildings would have active solar water heating systems installed by 2010, rising to 100 buildings by 2025. As with the domestic sector, these systems were assumed to consist of a single panel of 4 m^2, with a system efficiency of between 0.4 and 0.43 depending on the year.

It was also assumed that by 2010 two 1MW wind turbines would be installed locally to supply the services sector. Again, it was assumed that these were of similar type to those installed for the domestic sector. By 2025, five wind turbines would be in place.

Finally, for this sector it was assumed that CHP use would increase, with 2 MWe of plant installed by 2010 and 3MWe installed by 2025. Twenty percent of this plant would burn woodfuel. Again, some adjustments were required to the fuel demand variables. Demand for heat supplied by District Heating or CHP schemes for all sectors except health was increased from 1.5% to 2% and from 2% to 4% for 2010 and 2025 respectively. Demand for heat from conventional gas systems was reduced by similar amounts. For the health sector, use of CHP was already fairly high, with Milton Keynes hospital having a large CHP system, so it was assumed that use in this sector would not increase further.

8.4.2.2 Domestic Sector

It was assumed that 1000 households (1% of dwellings) would be fitted with photovoltaic systems by 2010, and that this would rise to 10,000 (7% of dwellings) by 2025. It was assumed that the average system would have a photovoltaic array of 9 m^2, an inverter efficiency of 0.9 in 2010 (rising to 0.95 by 2025), and an array efficiency of

0.18 in 2010 (0.2 in 2025). It was assumed that a further 1000 households would have active solar systems installed by 2010, rising to 10,000 households by 2025. These systems were assumed to consist of a single panel of 4 m^2, with a system efficiency of 0.415 in 2010, rising to 0.43 by 2025, giving an output per panel of approximately 2000 kWh per annum.

It was also assumed that by 2010 a total of nine wind turbines, dedicated to providing domestic housing with electricity would be installed locally. This was assumed to rise to fifteen turbines by 2025. The turbines were assumed to be an average of 1 MWe in size, with a coefficient of performance of 0.3 and array and operating losses of 10%. The mean wind speed for the area was taken to be 6.5m/s at a height of 10m.

Finally, for this sector it was assumed that CHP would be more widely used to supply heat and electricity to dwellings, with 1.5 MWe of plant installed by 2010 and 4 MWe installed by 2025. Twenty percent of this plant would burn woodfuel. As it was assumed that the plants would be sized to meet base load heating for the dwellings they supplied in order to maximise returns on investment, some adjustments were required to fuel demand. Demand for heat supplied by District Heating or CHP schemes was increased from 0% to 5% and 12% for 2010 and 2025 respectively. Demand for heat from conventional gas systems was reduced by similar amounts.

8.4.2.3 Industrial Sector

It was assumed that 500 photovoltaic systems, similar to those in the domestic and services sectors, would be fitted with by 2010, and that this would rise to 10,000 by 2025. In effect 1% of industrial sector roof space would be covered with photovoltaic systems in 2010, rising to 15% by 2025. It was assumed that a further 50 buildings would have active solar hot water systems installed by 2010, rising to 100 buildings by 2025. Again, similar properties were assumed for these systems as for the previous two sectors. It was assumed that by 2010 six wind turbines would be installed locally to supply the industrial sector. By 2025, ten 1 MW wind turbines would be in place.

Again, for this sector it was assumed that CHP use would increase, with 2.9 MWe of plant installed by 2010 and 3.5 MWe installed by 2025. Forty percent of this plant would burn woodfuel. No adjustments were necessary to the demand variables.

8.4.2.4 Transport Sector

For the transport sector, it was assumed that by 2010 100% of the bus fleet serving Milton Keynes had been converted to run on biodiesel. It was assumed that conversion rates in the private freight and private car sectors were lower, with only 50 cars being converted to biodiesel by 2010, although the number converted was assumed to reach 2000 by 2025, making up just over 1% of the private car fleet in Milton Keynes. For lorries, it was assumed that 40 lorries would be converted by 2010 (approximately 2% of the fleet). This was assumed to rise more rapidly after 2010, resulting in 340 converted lorries by 2025 (approximately 22% of the fleet).

8.4.3 Renewables B Scenario (RENB)

The same assumptions were used for this scenario as for Current Trends Continued (2000 base) except for those given below, dealing mainly with energy supply. The renewable energy systems assumed in this scenario are the same as those assumed for Renewables A, but there are more of them. Again, a few minor adjustments were necessary to those variables allocating demand to different fuel types, in order to match supply with demand for each fuel types. No changes were made to any economic growth or energy efficiency variables.

8.4.3.1 Services Sector

It was assumed that 3000 photovoltaic systems would be fitted with by 2010, and that this would rise to 30,000 by 2025. It was assumed that a further 150 buildings would have active solar systems installed by 2010, rising to 300 buildings by 2025. It was also assumed that by 2010 six wind turbines would be installed locally to supply the services sector. Again, it was assumed that these were of similar type to those installed for the domestic sector. By 2025, 15 wind turbines would be in place.

For this sector it was assumed that CHP use would increase to 3 MWe of plant installed by 2010 and 4.5 MWe installed by 2025. Sixty percent of this plant would burn woodfuel. Again, some adjustments were required to the fuel demand variables. Demand for heat supplied by District Heating or CHP schemes for the majority of sectors was increased from 1.5% to 12% and from 2% to 40% for 2010 and 2025 respectively. The Education, Residential, Health and Government sectors were seen as having a greater potential for CHP, so demand for these was increased to 80% by 2025.

The other sectors had little CHP in 2000 so demand in 2010 was assumed to be lower than that for the health sector at 24%. Demand for heat from conventional gas systems was reduced by similar amounts.

8.4.3.2 Domestic Sector

It was assumed that 3000 households (3% of dwellings) would be fitted with photovoltaic systems by 2010, and that this would rise to 30,000 (21% of dwellings) by 2025. A further 3000 households were assumed to have active solar systems installed by 2010, rising to 30,000 households by 2025.

It was also assumed that by 2010 a total of 18 wind turbines, dedicated to providing domestic housing with electricity would be installed locally. This was assumed to rise to 30 turbines by 2025.

Finally, for this sector it was assumed that 4.5 MWe of CHP plant would be installed by 2010 and 12 MWe installed by 2025. Sixty percent of the fuel burned in these plants would be woodfuel. As it was assumed that the plants would be sized to meet base load heating for the dwellings they supplied in order to maximise returns on investment, some adjustments were required to fuel demand. Demand for heat supplied by District Heating or CHP schemes was increased from 0% to 15% and 36% for 2010 and 2025 respectively. Demand for heat from conventional gas systems was reduced by similar amounts.

8.4.3.3 Industrial Sector

It was assumed that 1500 photovoltaic systems, similar to those in the domestic and services sectors, would be fitted by 2010, and that this would rise to 19,250 by 2025. In effect 3% of industrial sector roof space would be covered with photovoltaic systems in 2010, rising to over 85% by 2025. It was assumed that a further 150 buildings would have active solar hot water systems installed by 2010, rising to 300 buildings by 2025. Again, similar properties were assumed for these systems as for the previous two sectors. It was assumed that by 2010 eighteen wind turbines would be installed locally to supply the industrial sector. By 2025, 30 wind turbines would be in place.

Again, for this sector it was assumed that CHP use would increase, with 5.6 MWe of plant installed by 2010 and 10 MWe installed by 2025. All of this plant would burn woodfuel. No adjustments were necessary to the demand variables.

8.4.3.4 Transport Sector

For the transport sector, it was assumed that by 2010 100% of the bus fleet serving Milton Keynes had been converted to run on biodiesel. It was assumed that conversion rates in the private freight and private car sectors were lower, with 150 cars being converted to biodiesel by 2010, although the number converted was assumed to reach 6000 by 2025, making up just over 3% of the private car fleet in Milton Keynes. For lorries, it was assumed that 120 lorries would be converted by 2010 (approximately 8% of the fleet). This was assumed to rise more rapidly after 2010, resulting in 1020 converted lorries by 2025 (approximately 705 of the fleet).

8.5 SCENARIO ASSESSMENT

8.5.1 Energy Use

8.5.1.1 Current Trends Continued (2000 base) Scenario

In this scenario, the total delivered energy consumption of Milton Keynes is estimated to increase by 32%, from 22.4 PJ in 2000 to 24.6 PJ in 2010 (Figure 8.1). Consumption continues to rise beyond 2010, reaching 29.5 PJ by 2025. The majority of this increase is due to increases in the transport sector (Table 8.5), which almost doubles between 2000 and 2025.

In 2000 the total annual delivered energy demand was divided between the sectors as follows: domestic sector - 32%, services sector - 15%, industrial sector - 18% and transport sector – 35% (Table 8.5). By 2025 it was estimated that the domestic sector annual demand would have increased by 11% (to 7.9 PJ from 7.1 PJ in 2000)[16], the

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[16] These figures are not adjusted for temperature. A repeating pattern of temperature changes over 10 years was used in the model rather than 10 year averages, so considerable fluctuations occur, particularly in the domestic sector, due to changes in the weather.

services sector demand would have decreased by 9% (to 3.0 PJ) and the industrial sector annual demand was estimated to increase by 12% (to 4.6 PJ). Thus in 2025 it was estimated that the total delivered energy demand would be split between the four sectors as follows: domestic sector - 27%, services sector - 10%, industrial sector - 16% and transport sector - 47%.

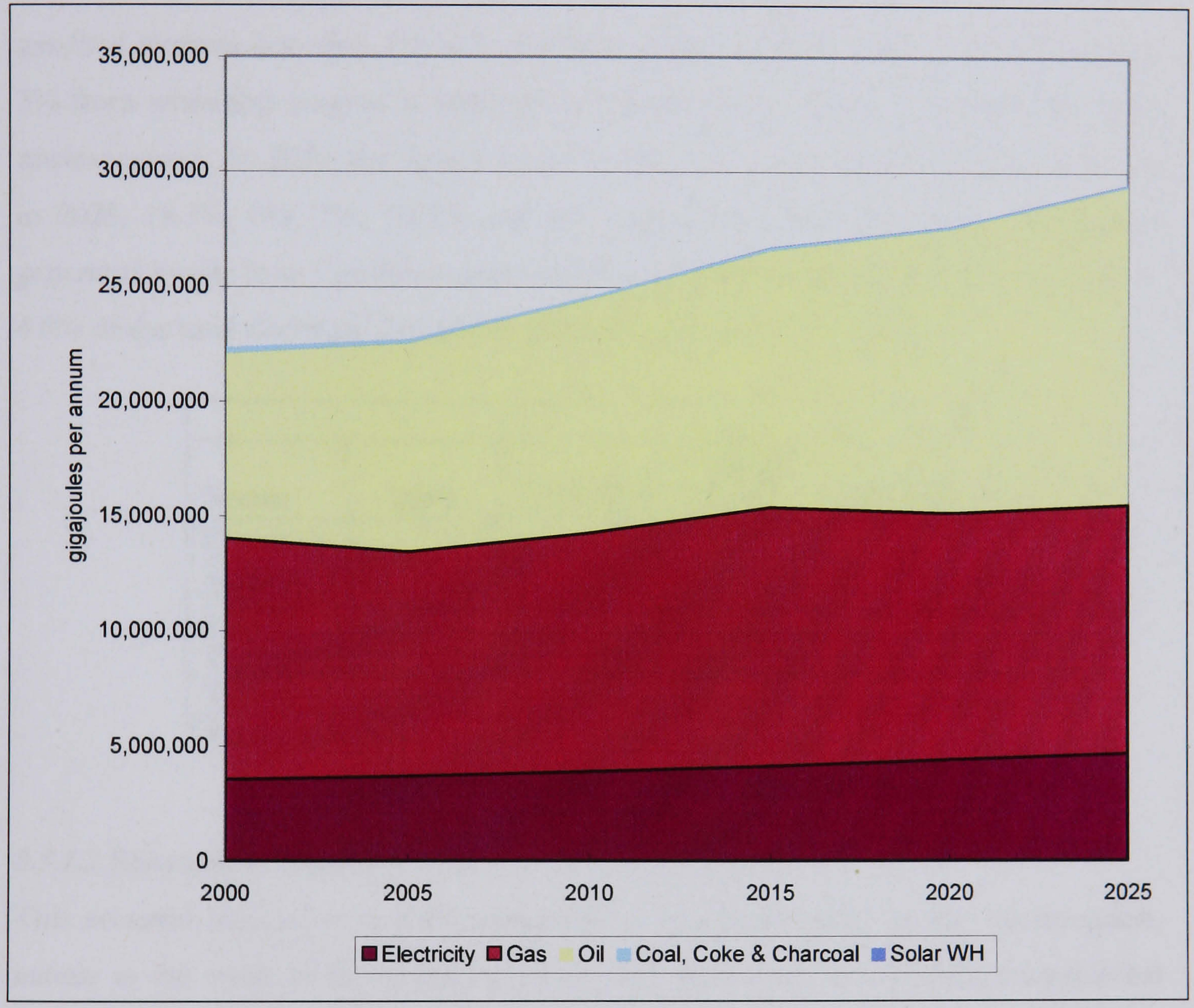

Figure 8.1: Energy Demand by Fuel for the Current trends Continued (2000 base) Scenario 2000-2025

The majority of the increase in transport sector energy demand was for oil (Figure 8.1). This is reflected in the overall trends of demand for different fuel types. Demand for oil rises from 8.1 PJ in 2000 to 13.9 PJ in 2025, increasing its share of demand from 36% to 47% over the same time period. Demand for solid fuels such as coal, coke and charcoal fell from 0.3 PJ to less than 0.1PJ between 2000 and 2025. Demand for electricity over the course of the modelled period rose from 3.6 PJ (16% of demand in 2000) to 4.7 PJ (16% of demand) in 2025. Demand for gas rose very slightly (10.4 PJ in 2000 to 10.8 PJ in 2025) but the share of total demand met by gas fell from 46% in 2000 to only 37% of total demand in 2025. A small amount of total energy demand was met by renewable sources – namely solar water heating (0.04 PJ in 2025), supplying 0.1% of total demand by the end of the modelled period.

The majority of electricity was supplied from the national grid, of this 39% was from gas-fired stations, less than 1% from oil-fired power stations, 30% from coal-fired and 3% from renewable sources in 2000, the remaining 28% is made up from imports and nuclear power. In 2010, the figures are 54%, 0%, 16%, 11% and 19% respectively, and in 2025, 78.5%, 0%, 7%, 10.5% and 4% respectively. The percentage of electricity generated locally from Combined Heat and Power (CHP) was estimated to contribute to 4.6% of the total electricity demand in 2000; this rose to 5% by 2025.

				PJ
		2025		
Sector	**2000**	**CTC00**	**RENA**	**RENB**
Domestic	7.1	7.9	7.8	7.7
Services	3.4	3.0	2.9	2.9
Industry	4.0	4.6	4.6	4.6
Transport	7.8	13.9	13.6	13.5
TOTAL	22.4	29.5	29.0	28.7

Table 8.5 Total Delivered Energy by Sector and by Scenario, 2000 to 2025.

8.5.1.2 Renewables A Scenario

This scenario resulted in a small reduction in overall delivered energy consumption, mainly as the result of the switch to using CHP away from less efficient conventional gas boilers. Total energy consumption was 24.5 PJ in 2010 and 29.0 PJ in 2025 (Figure 8.2). The effect of this reduction on the relative importance of the four sectors was negligible (Table 8.5).

In terms of fuel demand, there is a slight reduction in the demand for gas (by 0.4PJ and 0.9PJ in 2010 and 2025 respectively) compared with the same years in Current Trends Continued (Figure 8.1). This is a result of the switch to more efficient systems (CHP rather than boilers), a significant proportion of which were wood fuel-fired rather than gas-fired. Although it is not obvious from Figure 8.2, there is also a reduction in the demand for oil, with a small proportion of the transport fleet being converted to biofuels. This reduction amounts to 0.4PJ in 2010 and 0.9PJ in 2025 compared with the same years for Current Trends Continued. Renewable sources supply 3.1% of total energy demand in 2010, rising to 6.6% by 2025. The contribution renewable sources make to electricity demand is more pronounced. Local renewables (those specified explicitly in the assumption descriptions above) supply 5.7% of electricity demand in 2010, rising to 14.4% by 2025. Of this, in 2010, 0.16 PJ were generated by wind turbines, 0.02 PJ from PV systems and 0.05 PJ were generated by wood-fired CHP. For 2025 the figures are 0.31, 0.31 and 0.08 PJ respectively. It was assumed that a further 10% of electricity in 2010 is met from large-scale renewables schemes via the national grid; this decreases to 8% by 2025 as the proportion of electricity being supplied via the national grid decreases with increasing use of local renewable sources and CHP.

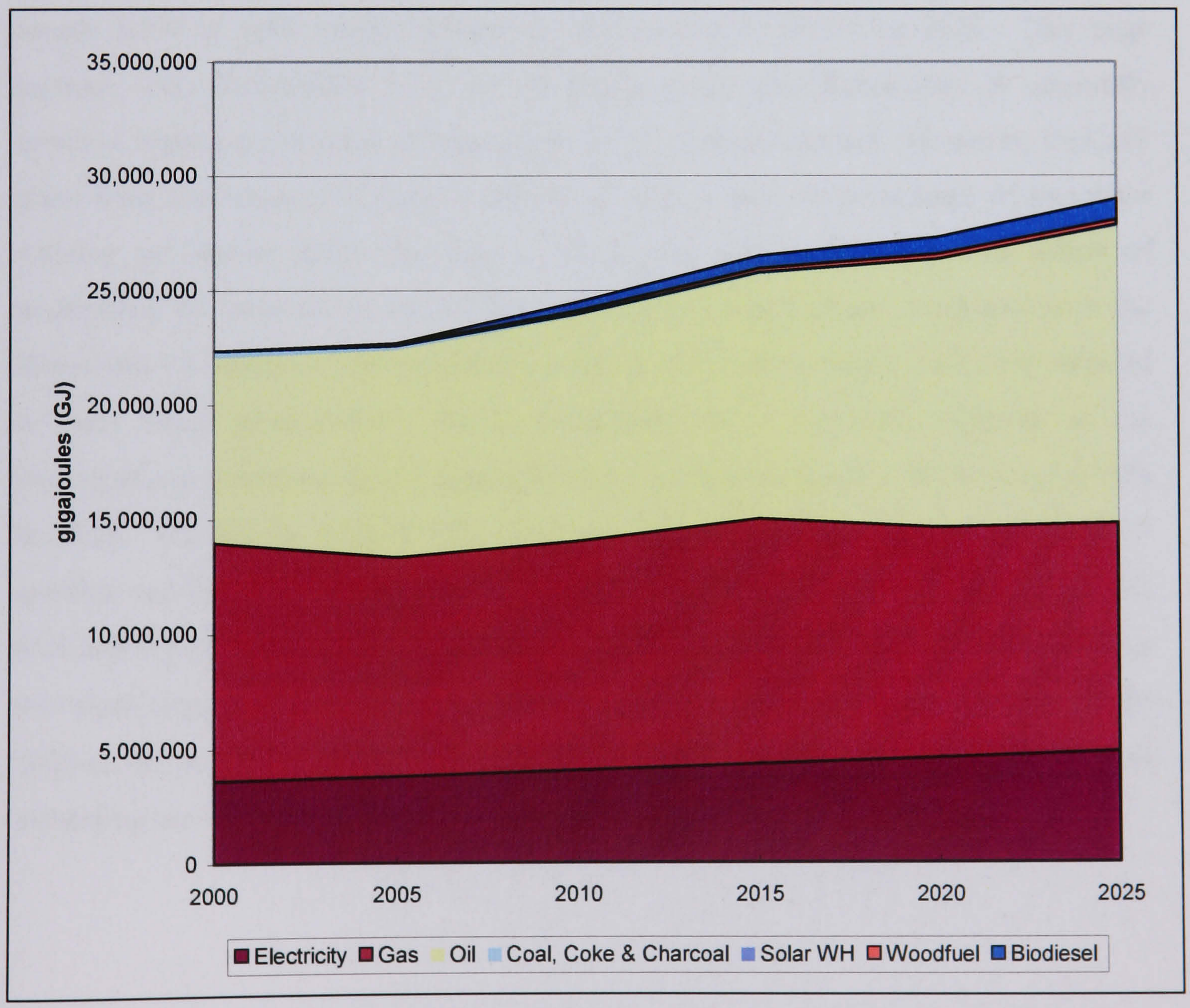

Figure 8.2: Energy Demand by Fuel Type for the Renewables A Scenario, 2000-2025

8.5.1.3 Renewables B Scenario

This scenario resulted in a further small reduction in total delivered energy consumption, again mainly as the result of the increased use of CHP with better efficiencies than in conventional gas boilers. Total energy consumption was 22.4 PJ in 2010 and 28.7 PJ in 2025 (Figure 8.3), a reduction of 3% in 2025 compared with 2025 if current trends had been continued. The effect of this reduction on the relative importance of the four sectors was negligible (Table 8.5).

In terms of fuel demand, there is a significant reduction in the demand for gas (by 0.8 PJ and 2.1 PJ in 2010 and 2025 respectively) compared with Current Trends Continued. This is a result of the switch to more efficient systems (CHP rather than boilers), the majority of which were wood fuel-fired rather than gas-fired. Figure 8.3 also shows a significant reduction in the demand for oil (1.5 PJ in 2025), with a large proportion of the commercial transport fleet being converted to run on biofuels. Renewable sources supply 8.5% of total energy demand in 2010, rising to 18.6% by 2025. This huge increase over Renewables A is not surprising given that Renewables B essentially involves tripling the number of renewable energy systems installed. However, for CHP plant both the amount of plant is effectively tripled and the percentage of this plant running on biofuel rather than gas or oil is also tripled. This gives the effect of multiplying the amount of wood-fired CHP by 9 in this scenario compared with the Renewables A scenario. The contribution renewable sources make to electricity demand is even more pronounced. Local renewables (those specified explicitly in the assumption descriptions above) supply 23% of electricity demand in 2010, rising to 52% by 2025. Of this, in 2025, 0.9 PJ were generated by wind turbines, 0.8 PJ from PV systems and 0.6 PJ were generated by wood-fired CHP. For 2010 the figures are 0.5, 0.06 and 0.3 PJ respectively. It was assumed that a further 8% of electricity in 2010 is met from large-scale renewables schemes via the national grid; this decreases to 5% by 2025 as the proportion of electricity being supplied via the national grid decreases with increasing use of local renewable sources and CHP.

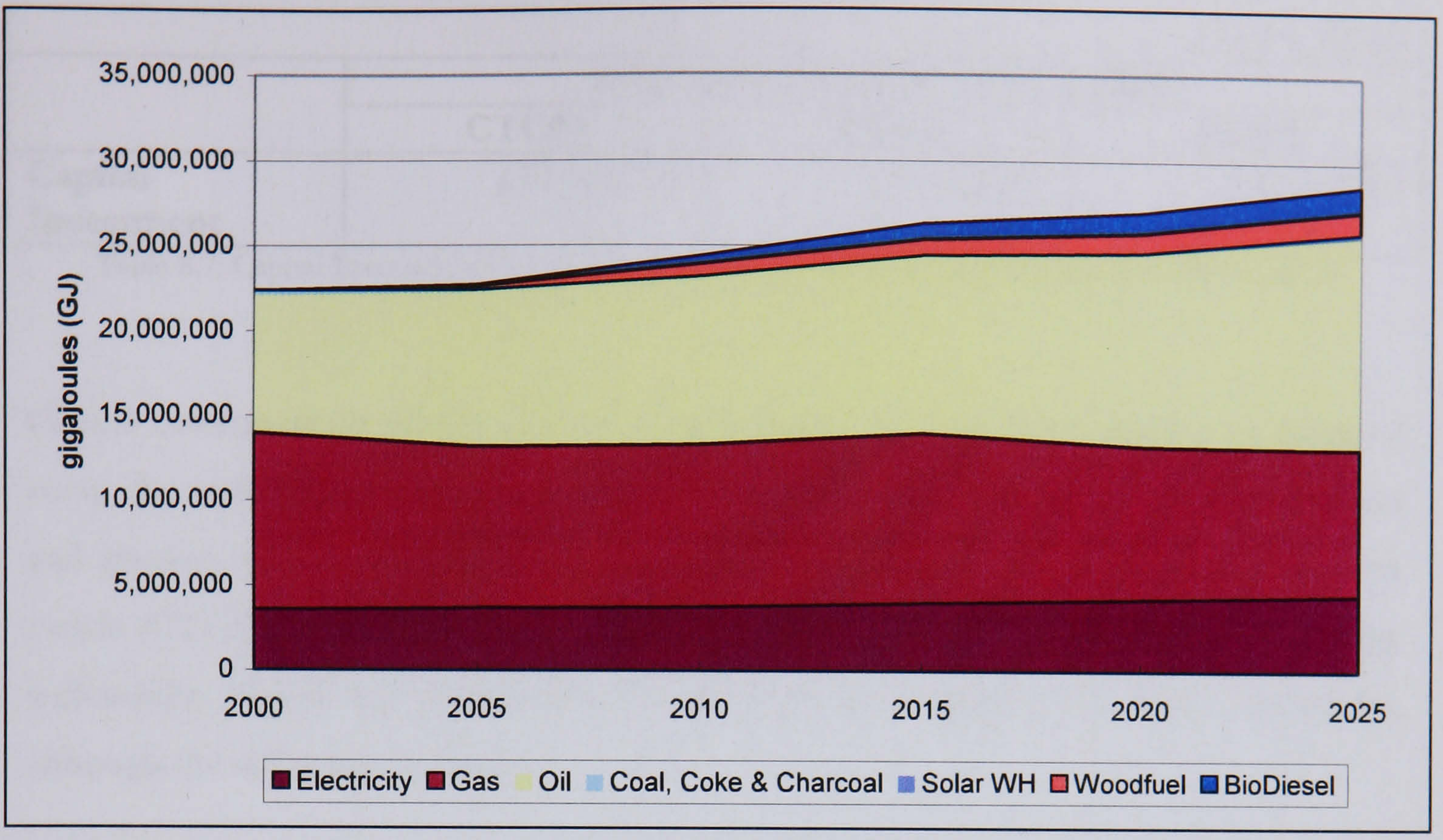

Figure 8.3: Energy Demand by Fuel Type for the Renewables B Scenario

8.5.2 The wider impacts

This section presents the non-energy impacts of the energy scenarios, e.g. emissions, land-use, and monetary costs.

8.5.2.1 Energy Expenditure

Monetary costs were evaluated for a range of fuel prices using the methodology described in Chapter Five. Table 8.6 shows the total amount of energy purchased between January 1990 and December 2025 and the value of that purchased, calculated on the basis described above. As discussed above a discount rate of 5% was used. Figures are given in 1990 £s. As previously noted, energy expenditure has been calculated using the market price and not the marginal cost of energy supply.

	MILTON KEYNES (1990 to 2025)		
	CTC00	**RENA**	**RENB**
Primary Energy Consumption *(PJ)*	820	818	799
Energy Expenditure *(£million 1990)*	£1455 to £2614	£1485 to £2620	£1361 to £2496

Table 8.6: Total Energy Purchased by Milton Keynes by Scenario, 1990 to 2025.

			£million (1990)
	MILTON KEYNES (1990 to 2025)		
	CTC00	**RENA**	**RENB**
Capital Investment	£73 to £790	£76 to £800	£80 to £813

Table 8.7: Capital Invested in Energy Management by Milton Keynes by Scenario, 1990 to 2025

Capital investment in energy efficiency technologies has been calculated as a range of costs, the exact figure depending on the choice of supplier of individual technologies and precise specifications. As can be seen from Table 8.7, continuation of current trends (CTC00) is likely to lead to the lowest level of capital expenditure on energy technology, whilst the Renewables B Scenario is potentially the most expensive, although the difference is small.

			£million (1990)
	MILTON KEYNES (1990 to 2025)		
	CTC00	**RENA**	**RENB**
Total Expenditure	£1528 to £3404	£1561 to £3420	£1441 to £3309

Table 8.8: Total Expenditure 1990 to 2025 by Scenario

The Renewables B Scenario involved lower total expenditure than Current Trends Continued (2000 base) Scenario (Table 8.8). The Renewables A Scenario had the highest fuel costs. The performance of the scenarios in terms of total monetary costs was dominated by fuel costs. The Current Trends Continued (2000 base) Scenario had the highest range of possible costs.

8.5.2.2 Greenhouse Gas Emissions

Under the Current Trends Continued (2000 base) Scenario, carbon dioxide emissions from the domestic, services and industrial sectors remained relatively constant over the 25-year period at 0.5, 0.2 and 0.3 million tonnes respectively (Figure 8.4). The contribution by the transport sector rose from 0.6 million tonnes in 2000 to 1.0 million tonnes in 2025, an increase of 67%, resulting in an overall increase of 25% between 2000 and 2025. By 2025 the transport sector accounts for half of all emissions.

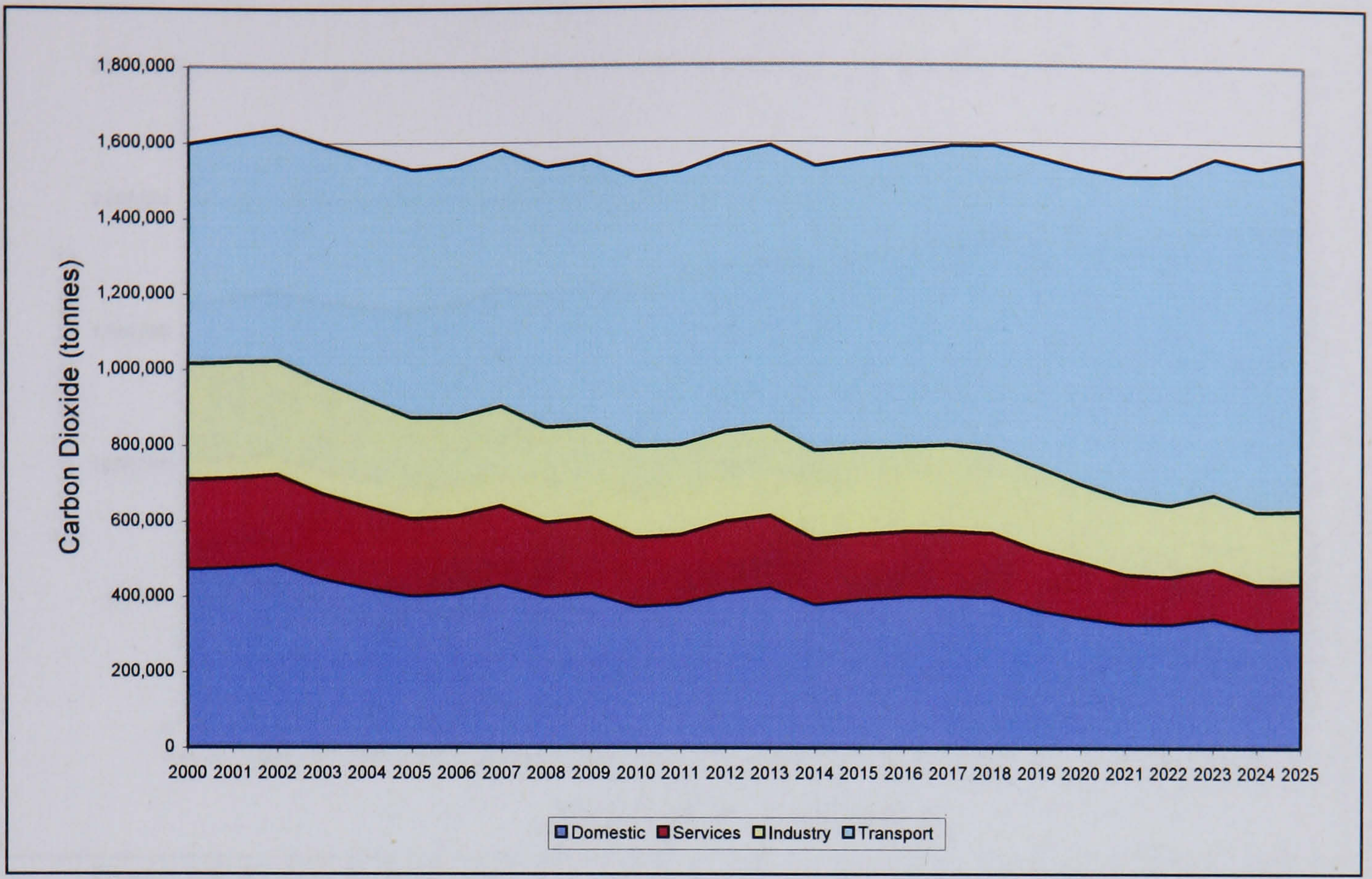

Figure 8.6: Carbon Dioxide Emissions by Sector for the Renewables B Scenario, 2000-2025

Over the 35-year period from 1990 to 2025, greenhouse gas emissions were lowest from the Renewables B Scenario and highest from the Current Trends Continued Scenario (2000 base), as expected.

			Thousand Tonnes
	MILTON KEYNES (1990 to 2025)		
	CTC00	**RENA**	**RENB**
Carbon Dioxide	71,800	70,000	66,100
Nitrogen Oxides	128	126	120
Methane	6.58	6.51	6.08

Table 8.9: Greenhouse Gas Emissions by Scenario, 1990 to 2025.

8.5.2.3 Local Air Pollution

This section presents the results for each scenario in terms of emissions that are produced locally (within the borough) and will affect local air quality. Without using a dispersion model it is difficult to predict the precise effects that these emissions will have on local air quality. However, it is reasonably safe to assume the higher the emissions of these pollutants the poorer the local air quality is liable to become.

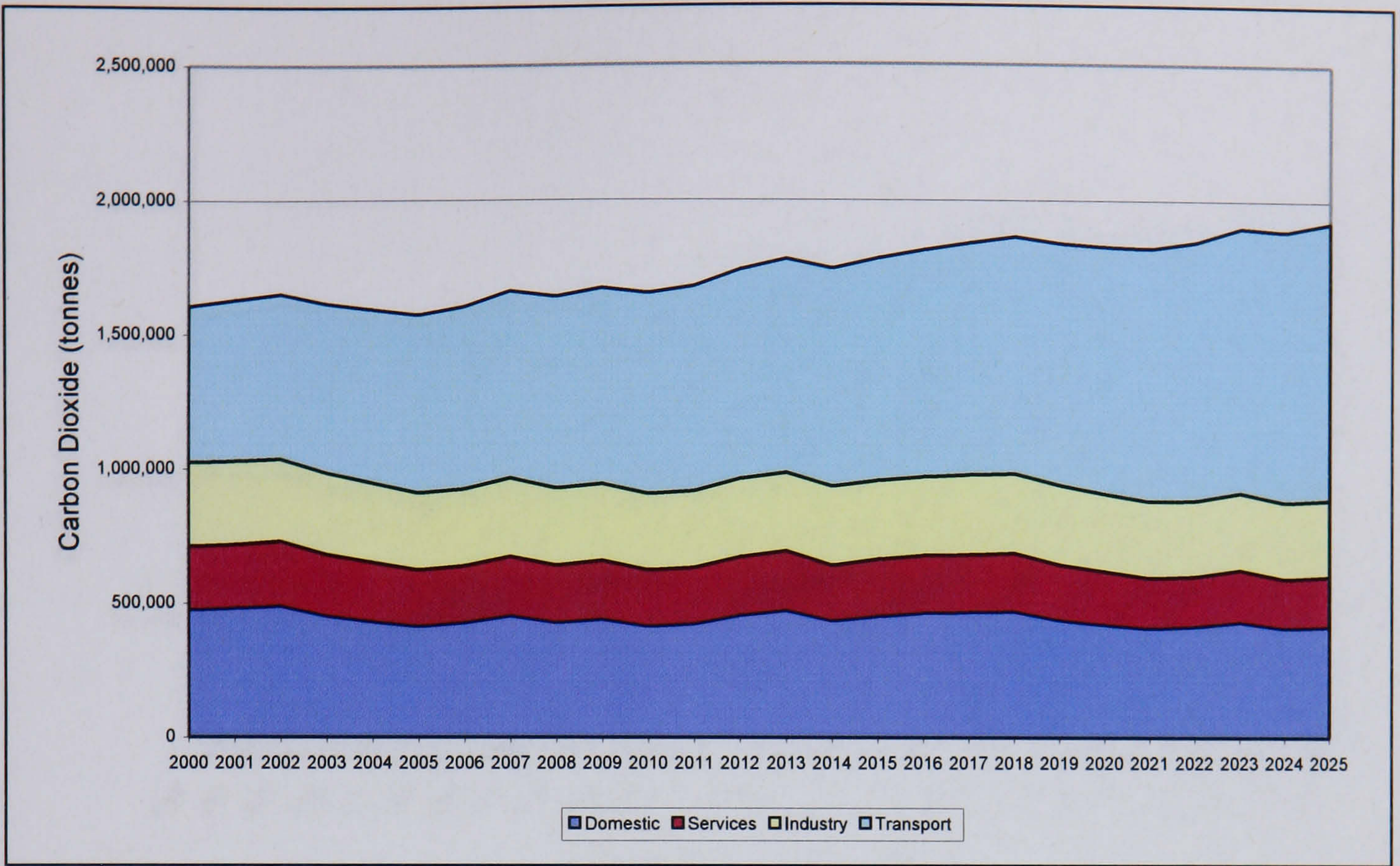

Figure 8.5: Carbon Dioxide Emissions by Sector for the Renewables A Scenario, 2000-2025

Renewables B resulted in carbon dioxide emissions being stabilised at below current rates of emissions (Figure 8.6). However, if the transport sector continued to grow beyond 2025 and with the uptake of certain renewables in some sectors nearing capacity, carbon dioxide emissions could well rise above 2000 levels shortly beyond the modelled period if no measures were taken to reduce transport energy consumption.

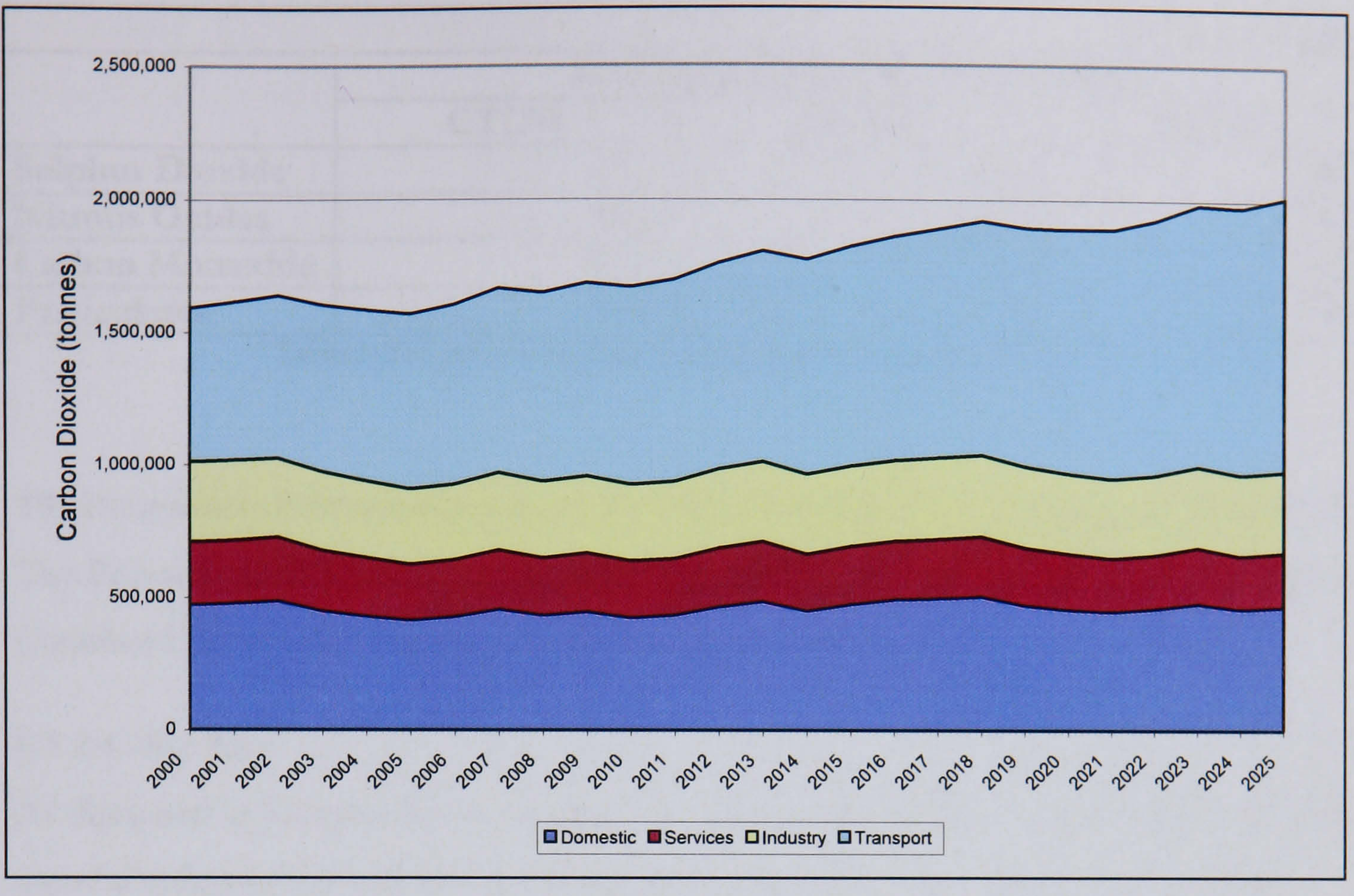

Figure 8.4: Carbon Dioxide Emissions by Sector for Current Trends Continued Scenario (2000 base), 2000-2025

The Renewables A Scenario shows a slight reduction in carbon dioxide emissions compared with Current Trends Continued. In 2025, 1.9 million tonnes of carbon dioxide are emitted (Figure 8.5) compared with 2.0 million tonnes with Current Trends Continued. The domestic, services and industrial sectors all show a slight reduction in emissions, but the reduction is most marked in the domestic sector where emissions fall from 0.5 to 0.4 million tonnes in 2025 compared with Current Trends Continued. In this scenario the transport sector accounts for 53% of carbon dioxide emissions in 2025.

			Thousand Tonnes
	MILTON KEYNES (1990 to 2025)		
	CTC00	**RENA**	**RENB**
Sulphur Dioxide	273	264	260
Nitrous Oxides	83.0	80.4	78.7
Carbon Monoxide	9.20	8.82	8.62
Particulates	8.00	7.73	7.59

Table 8.10: Local Air Polluting Emissions by Scenario 1990-2025

The Renewables B Scenario produces the least of all the local air pollutants (Table 8.10). The Renewables A Scenario shows some improvement compared with Current Trends Continued (2000 base) Scenario for all local air pollutants.

8.5.2.4 Acid Rain

As discussed in Chapter Seven, sulphur dioxide emissions from power stations provide a useful indicator for acid rain in the absence of detailed meteorological information.

		Thousand Tonnes
MILTON KEYNES (1990 to 2025)		
CTC00	**RENA**	**RENB**
140	140	132

Table 8.11: Sulphur Dioxide Emissions from Power Stations Resulting from Energy Consumption in Milton Keynes by Scenario, 1990-2025.

The Renewables B scenario results in reduced power station sulphur dioxide emissions compared with Current Trends Continued (2000 base) Scenario (Table 8.11). This is due to the assumption in scenario that a higher proportion of electricity would be generated locally through the use of CHP, in addition to use of renewable energy. The Renewables A Scenario does not result in a significant reduction of sulphur dioxide emissions.

8.5.2.5 Other Impacts

Other impacts from each of the scenarios are listed in Tables 8.12 to 8.14.

All the scenarios would require additional land. For the Current Trends Continued Scenario and the Renewables A Scenario additional generating capacity is likely to be required to meet the growth in electricity demand that is not met from CHP or renewables. Both of the renewables scenarios require small amounts of additional land to site wind turbines. Both the new power stations and the wind turbines will have some visual impact on the surrounding area. These impacts can be minimised with careful siting and, in the case of power stations, use of landscaping. Careful siting may be more difficult for the Renewables B option than for Renewables A, in respect of wind turbines, due to the larger numbers involved if there is a shortage of suitable sites. Some minor noise pollution would also be expected in all three scenarios, some of it affecting the residents of Milton Keynes directly (mainly from locally placed wind turbines). Waste incineration, which is part of the Renewables B Scenario, can produce unpleasant odours.

The manufacturing of photovoltaic modules requires use of several hazardous materials. However, the risk is no greater than that of many manufacturing processes and safety standards are in place to reduce the risk to workers. This affects both renewables scenarios. There is a fire risk when handling petroleum products, natural gas, coal (from coal dust) and wood chips. Coal dust and dust from wood chips also pose a health hazard and can cause lung damage if not handled correctly. The dust hazard from wood chips can be mitigated through the use of pellets. This risk is present in all five scenarios as use of fossil fuels continues in all of them. The hazards from wood chips are an issue for the both Renewables A and Renewables B Scenarios.

The greater use of CHP and local renewable sources in the two renewables scenarios can also be expected to lead to some job creation. If these schemes are run cooperatively, they could also increase the sense of community and boost the local rural economy. These two scenarios also benefit from a diversity of sources of electricity and less reliance on oil, giving greater security of supply than experienced under the Current Trends Continued (2000 base) Scenario.

8.5.3 Analysis of the Results

Milton Keynes energy consumption could grow by over 30% over the 25 years if current trends in energy demand do not change (i.e. if current trends continue), resulting in an increase in carbon dioxide emissions of 25%. This estimate of growth is based on relatively conservative estimates of economic growth for the borough.

The level of renewables assumed in Renewables A is not sufficient to achieve the 10% renewable electricity target set by Government for 2010 by relying on local systems alone. However, it remains unclear what role large-scale schemes outside the immediate area of Milton Keynes will play in achieving this target.

Renewables B resulted in a stabilising of carbon dioxide emissions below current levels and more than met the target of 10% of electricity from renewable sources by 2010.

There were no significant differences between the two renewables scenarios in terms of environmental impacts. Renewables B generated fewer emissions than Renewables A. However, it may be more difficult to locate the solar panels and wind turbines assumed in Renewables B unobtrusively, as the numbers of these, and of solar panels in particular, assumed in this scenario is high. The two renewables scenarios were only slightly more expensive in terms of fuel costs and capital outlay than the Current Trends Continued Scenario (2000 base).

8.6 Methodology Feedback

MKEA were generally very pleased with the performance of the energy model (DREAM-MK) and were interested in using the model output as a monitoring tool, to assess the performance of the renewable energy strategy in five years time. The National Energy Foundation (one of the members of MKEA) expressed an interest in purchasing a licence for DREAM and accompanying spreadsheets and databases, as they felt that the tool would prove extremely useful in the production of local and regional energy strategies.

A number of ideas were discussed with MKEA that could not be easily accommodated without substantially adapting existing routines or adding new routines into the DREAM-MK model. These included the use of solar PV on street furniture, the use of passive solar energy for heating, the use of natural ventilation, heat pumps, micro-CHP, hybrid vehicles, hydrogen fuel cell technology and the use of landfill gas. MKEA were also interested in the effect of the Climate Change levy on energy demand within the city.

The model often required a much greater level of detail on each renewable source than MKEA ideally would have liked to specify, and some of this additional data was not readily available to MKEA. For example, initially MKEA provided data on the number of households that would be fitted with solar photovoltaic panels. Additional information on the assumed module efficiency and the size of the arrays was required. This data then still needed translating into the correct format for the model, which required the percent of suitable (south-facing) roof-space to be entered rather than the number of households fitted. The process of collecting and passing the information regarding the model assumptions to the author required several iterations, as additional data requirements became apparent or because it was unclear as how to interpret and process the information provided into a format suitable for input into the model.

A further concern expressed about the energy model, was the amount of data required to set the model up. This concern was also expressed by Webber and Fleming (2003) in their review of tools that could be used to compile a greenhouse gas emissions inventory for the East Midlands region.

MKEA were very interested in the impacts matrix and, in particular, by the calculations of fuel costs, capital costs and emissions for each scenario. They found these particularly useful, especially in the light of their proposed mechanism for achieving zero growth in carbon dioxide emissions – i.e. using a sum payable by developers via the planning obligations system to offset future emissions from a new development. Ideally, MKEA would like to see the cost calculation spreadsheets linked to the model, so that the process of calculating costs from the model output is automated; similarly with other quantifiable impacts, such as land-take.

MKEA felt that the impact matrices needed to be accompanied by impact statements (as indeed they were, see section 8.5 above, for example). They gave a number of reasons for this opinion. Firstly, the impact statements included information on the energy demand in the final year of the modelled period (2025 in this case); information on the energy demand trends and a break down of energy demand by sector. All this information was considered to be as important, if not more important, than total energy consumption over the modelled period (1990-2025), particularly when considering the long-term horizons of sustainable development. Secondly, the impact statements could also serve to provide explanatory detail that cannot be included in the summary matrix. Thirdly, the impact statements provide a comparison of the scenarios and highlight key similarities and differences.

The layout and level of detail in the impact statements was considered to be "about right", although, perhaps a better method could be found for highlighting the uncertainty of the impact data (denoted by the thickness of the line dividing each cell of the matrix). The tables were thought to be too large to quickly absorb the information presented, but had considerable advantage over the usual "pluses and minuses" approach as useful additional information was provided about who would be affected, when, and mitigation possibilities.

The presentation of the matrices was considered to be generally helpful. However, it was not easy to quickly ascertain how thick a particular line was and thus the certainty of the information presented, especially when the line was isolated so there was nothing to compare it with.

In summary, the assessment framework was found to be useful and it was felt that it would help improve the policy-making process.

8.7 Key to Tables 8.12-8.14

Accuracy of Information

Accurate Information

Reasonably Accurate Information

Reasonable Estimate

Rough Estimate

Unknown Accuracy

Probability of Impact Occurring
P(H) - High Risk, >60%
P(E) - Even Risk, 40-60%
P(L) - Low Risk, >40%
P(?) - Risk Unknown
P(75) - 75% probability of impact occurring

Impact Duration
C - Commissioning
O - Project
D - Decommissioning
M - Manufacturing
A - Impact continues beyond the life of the project

Table 8.12: Summary of Impacts in the Current Trends Continued (2000 base) Scenario, 1990-2025

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
Total Energy Consumption (PJ)	**Electricity**			100 PJ from National Grid		Nil	
	Gas			366 PJ Natural Gas			
	Oil			345 PJ			
	Solid Fuel			8.0 PJ			
	Total			820 PJ		Nil	
1. Capital Cost	*£(1990) millions*	£73 to £790	C, P(H), Businesses and Households	Included in Fuel Costs			
2. O&M Costs	**a. Fuel Costs** *£(1990) millions*	Negligible		£1455 to £2614	O, P(H), Households, Businesses in Council Area		
	b. Other O&M Costs	Negligible		Included in Fuel Costs			
3. Land Use, Landscape and Open Land				Possible use of agriculture land and/or wilderness areas for:			
				a) Coal production	COD, P(H), Tourists, Rural Communities;		
				b) Siting of new power stations	COD, P(E), Local Residents		
				c) New power lines	CD, P(L), Tourists, Local Communities		
4. Noise				Explosive noise from Oil surveying,	C, P(L), Costal Settlements,		
				Significant noise from coal mining and preparation	COD, P(H), Tourists, Rural Communities		
5. Visual Intrusion				Oil and Gas rigs visible from shoreline,	COD, P(L), Tourists, Costal Settlements,		
				Scarred lanscape from coal mining,	COD, P(H), Tourists, Rural Communities,		
				Transmission Pylons,	COD, P(?), Tourists, Rural Communities,		
				Power Plants	COD, P(H), Tourists, Rural Communities		

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
6. Transport	**a. Power Transmission**			Power Plants often need to be located near significant sources of water - power lines needed	COD, P(?), Residents along route		
	b. Other Transport			Increased road transport to transport coal and oil	COD, P(H), Tourists, Rural Communities		
7. Health and Safety	**a. Hazardous Materials**						
	b. Ionising Radiation			Low rates from radio-active sourced nuclear tools used in oil and gas production, Risk of leaks from Nuclear plants	CODA, P(?), Workers; ODA, P(L), depends on size of accident/leak - Workers, Local Communities to Continental.		
	c. Other Risks	reduction of sick building syndrome	O, P(?), Businesses, Workers	Risks from dust, particulates, noise, methane explosions, tunnel collapse from coal mining and preparation	COD, P(H), Workers		
8. Ecology				Disturbance from large projects on greenfield sites,	COD, P(H), -;		
				marine life disturbed by seismic oil surveys, clearance of land to construct pylons	C, P(L), Fishermen; COD, P(E), Tourism, Rural Communities		
9. Job Creation/Loss							
10. Liveability of Urban and Rural Areas	**a. Security**			Cost of providing extra security over and above that supplied by the plant owners	ODA, P(?), Nat. Gov.		
	b. Electromagnetic Interference						
	c. Recreation			surface subsidence, changes to familiar scenery. Some impact on comfort and amenity	ODA, P(H), Tourists, Rural Communities		
	d. Odours and Smells						
	e. Building Quality	Increased levels of comfort, increased levels of lighting	O, P(H), Employees and Households				

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
11. Water Conservation and Quality	**a. Water Usage**						
	b. Water Quality			225 tonnes of oil spilt due to oil production, 5965 tonnes discharged on drill cuttings and 4850 tonnes with produced water. Current regs limit oil content of water to 40ppm, also pipeline leaks	CODA, P(H), -		
	c. Groundwater			Potential contamination from organic compounds and metals released during coal gasification. Soluble salts and phenolic compounds in the ash and char remains	CODA, P(?), -		
	d. Drainage Patterns			Changes to water drainage patterns due to subsidence leading to changes in both surface topography and underlying strata	CODA, P(?), -		
12. Resources	**a. Natural Resources**			Depletion of Oil, Gas, Coal and Uranium Reserves	OA, P(100), -		
	b. Infrastructure/ Man-made Resources			Cost to the government and/or local authority of providing additional infrastructure when new power plants are built varies depending on local circumstances	COA, P(H), Nation and/or Local Communities		

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
13. Greenhouse Gas Emissions	**a. Carbon Dioxide**	Used as blowing agent for some foamed plastic insulation materials. Some releases during production	M, P(H), -	72 million tonnes + emissions from gas flaring, leakages, and gas used as part of the oil production process	COA, P(H), -		
	b. Nitrogen Oxides			128 million tonnes + emissions from gas flaring, leakages, and gas used as part of the oil production process	COA, P(H), -		
	c. Methane			6600 tonnes+ small amounts from gas flaring, leakages, and gas used as part of the oil production process	COA, P(H), -		
	d. CFCs	CFCs used as blowing agents in the production of some foamed plastic insulation materials. HFCs and CO2 also used.	M, P(H), -				
14. Air Quality	**a. Sulphur Dioxide**			140 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 273 thousand tonnes locally	COA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	b. Nitrogen Oxides			45 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 83 thousand tonnes locally	COA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
14. Air Quality continued...	**c. Carbon Monoxide**			20 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 9.2 thousand tonnes locally	COA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	d. VOC			3.0 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 3.5 thousand tonnes locally	COA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	e. Particulates			airbourne dust can be combated, 0.02% of coal lost during transport loading, coal dust from rail transport, 8.4 tonnes nationally, 8.0 tonnes locally from burning fossil fuels	COA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	f. Thermal Emissions			some but low	COD, P(L), Local Communities		
	g. Other Emissions			potential leakage of 300gms/GJ H2 and H2S	COD, P(?), Local Communities		
15. Land and Soil Quality	**a. Heavy Metals**			6 to 9 g/GJ from coal preparation processes	O, P(H), Workers, Local Communities, Wider		
	b. Soil			opencast mining - severe soil disturbance, reduces soil fertility, problems of compaction	CODA, P(H), Local Communities		
	c. Solid and Liquid Waste			Oil mud spills from drilling, spoils from coal mining and preparation, radio-active material from nuclear power plants	CO, P(H), -; CO, P(H), Local Communities; CODA, P(H), Local Communities		
	d. Other Pollutants						

Table 8.13: Summary of Impacts in the Renewables A Scenario, 1990-2025

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
Total Energy Consumption	**Electricity**			100 PJ from National Grid		14 PJ	
	Gas			354 PJ Natural Gas			
	Oil			338 PJ			
	Solid Fuel			7.2 PJ		13 PJ	
	Total			818 PJ		27 PJ	
1. Capital Cost	**£(1990) millions**	£110 to £1,164	C, P(H), Businesses and Households	Included in Fuel Costs		Included in Fuel Costs	
2. O&M Costs	**a. Fuel Costs**	Negligible		£1485to £2620	O, P(H), Households, Businesses in Council Area	Included in (a)	
	b. Other O&M Costs	Negligible		Included in Fuel Costs		Included in Fuel Costs	
3. Land Use, Landscape and Open Land				Possible use of agriculture land and/or wilderness areas for: a) Coal production b) Siting of new power stations c) New power lines	 COD, P(H), Tourists, Rural Communities; COD, P(E), Local Residents CD, P(L), Tourists, Local Communities	0.04 km2 for wind turbine foundations and access roads, 250,000 m2 roof space, 30 small engine houses	COD, P(H), Rural Communities inside and/or outside Council Area
4. Noise				Explosive noise from Oil surveying, Significant noise from coal mining and preparation	C, P(L), Costal Settlements, COD, P(H), Tourists, Rural Communities	Careful siting of turbines needed, some but minimal noise from extra traffic and engines	COD, P(H), Rural Communities inside and/or outside Council Area,
5. Visual Intrusion				Oil and Gas rigs visible from shoreline, Scarred lanscape from coal mining, Transmission Pylons, Power Plants	COD, P(L), Tourists, Costal Settlements, COD, P(H), Tourists, Rural Communities, COD, P(?), Tourists, Rural Communities, COD, P(H), Tourists, Rural Communities	Some can be minimised with careful siting, and education programme	COD, P(?), Residents near sites

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
6. Transport	**a. Power Transmission**			Power Plants often need to be located near significant sources of water - power lines needed	COD, P(?), Residents along route	Grid lines needed from wind turbine sites to city	O, P(?), Rural Communities, Tourists outside Council Area
	b. Other Transport			Increased road transport to transport coal and oil	COD, P(H), Tourists, Rural Communities	Transportation of waste to plant of forestry residue	O, P(H), Local Residents
7. Health and Safety	**a. Hazardous Materials**					Manufacture of PV can involve the use of hazarous materials: dioborane, silane, silicon tetraflouride gases, cadmium, tellurium, copper and indium	M, P(L), Manufacturing Staff
	b. Ionising Radiation			Low rates from radio-active sourced nuclear tools used in oil and gas production, Risk of leaks from Nuclear plants	CODA, P(?), Workers;. ODA, P(L), depends on size of accident/leak - Workers, Local Communities to Continental		
	c. Other Risks	reduction of sick building syndrome	O, P(?), Businesses, Workers	Risks from dust, particulates, noise, methane explosions, tunnel collapse from coal mining and preparation	COD, P(H), Workers	Fire risk from stored dry straw.. Storage of wood chips can lead to spore release which in a confined space, represents a health hazard. - Prolonged exposure can lead to Farmer's lung. Controlled by wearing face masks	O, P(L), Rural Communities inside and/or outside Council Area, O, P(L), Project Workers
8. Ecology				Disturbance from large projects on greenfield sites, marine life disturbed by seismic oil surveys, clearance of land to construct pylons	COD, P(H), -;. C, P(L), Fishermen; COD, P(E), Tourism, Rural Communities	V. little damage with careful siting of projects, slight influence on mircoclimate below and behind wind turbines	O, P(L), -

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
9. Job Creation/Loss						Employment of local labour force in construction and maintenance	COD, P(?), Rural Communities and Local Communities
10. Liveability of Urban and Rural Areas	**a. Security**			Cost of providing extra security over and above that supplied by the plant owners	ODA, P(?), Nat. Gov.	Income for rural economies, security of supply, cost of energy not vulnerable to fluctuations as determined by capital costs more jobs, less reliance on imports esp. if use UK products, Nat. Gov. looses tax revenue	COD, P(?), Rural Communities near site; O, P(L), Residents. O, P(L), Nation
	b. Electromagnetic Interference					Not usually a problem, similar to that of static buildings	O, P(L), Rural Communities near site
	c. Recreation			Surface subsidence, changes to familiar scenery. Some impact on comfort and amenity	ODA, P(H), Tourists, Rural Communities		
	d. Odours and Smells					Specialist waste combustion can emit unpleasant odours - but can be minimised	O, P(E), Local Residents
	e. Building Quality	Increased levels of comfort, increased levels of lighting	O, P(H), Employees and Households				
11. Water Conservation and Quality	**a.Water Usage**					Some but low - CHP engine cooling water make up	O, P(H), -
	b. Water Quality			225 tonnes of oil spilt due to oil production, 5965 tonnes discharged on drill cuttings and 4850 tonnes with produced water. Current regs limit oil content of water to 40ppm, also pipeline leaks	CODA, P(H), -		
	c. Groundwater			Potential contamination from organic compounds and metals released during coal gasification. Soluble salts and phenolic compounds in the ash and char remains	CODA, P(?), -		

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
11. Water Conservation and Quality co ntinued....	**d. Drainage Patterns**			changes to water drainage patterns due to subsidence leading to changes in both surface topography and underlying strata	CODA, P(?), -		
12. Resources	**a. Natural Resources**			Depletion of Oil, Gas, Coal and Uranium Reserves	OA, P(100), -		
	b. Infrastructure/ Man-made Resources			Cost to the government and/or local authority of providing additional infrastructure when new power plants are built varies depending on local circumstances	COA, P(H), Nation and/or Local Communities		
13. Greenhouse Gas Emissions	**a. Carbon Dioxide**	Used as blowing agent for some foamed plastic insulation materials. Some releases during production	M, P(H), -	70 million tonnes + emissions from gas flaring, leakages, and gas used as part of the oil production process	COA, P(H), -		
	b. Nitrogen Oxides			126 million tonnes + emissions from gas flaring, leakages, and gas used as part of the oil production process	COA, P(H), -		
	c. Methane			6500 tonnes+ small amounts from gas flaring, leakages, and gas used as part of the oil production process	COA, P(H), -		
	d. CFCs	CFCs used as blowing agents in the production of some foamed plastic insulation materials. HFCs and CO2 also used.	M, P(H), -				

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
14. Air Quality	**a. Sulphur Dioxide**			142 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 264 thousand tonnes locally	COA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	b. Nitrogen Oxides			45 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 80 thousand tonnes locally	COA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	c. Carbon Monoxide			20 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 8.8 thousand tonnes locally	COA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	d. VOC			3.0 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 3.4 thousand tonnes locally	COA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	e. Particulates			airbourne dust can be combated, 0.02% of coal lost during transport loading, coal dust from rail transport, 8.5 tonnes nationally 7.7 tonnes locally from burning fossil fuels	COA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	f. Thermal Emissions			some but low	COD, P(L), Local Communities	Some but majority used to produce hot water	O, P(H), Residents near site
	g. Other Emissions			potential leakage of 300gms/GJ H2 and H2S	COD, P(?), Local Communities	Low levels of dioxins, some acidic gases from burning waste.	O, P(H), Residents near site

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
15. Land and Soil Quality	**a. Heavy Metals**			6 to 9 g/GJ from coal preparation processes	O, P(H), Workers, Local Communities, Wider	Trace from waste and biomass, some from PV which need careful handling when decommission -ing	O, P(H), Residents near site , D, P(L), Workers
	b. Soil			opencast mining - severe soil disturbance, reduces soil fertility, problems of compaction	CODA, P(H), Local Communities		
	c. Solid and Liquid Waste			Oil mud spills from drilling, spoils from coal mining and preparation, radio-active material from nuclear power plants	CO, P(H), -; CO, P(H), Local Communities; CODA, P(H), Local Communities		
	d. Other Pollutants					Minor amounts of oil from greasing turbines, Some pollution from manufacturing process but within industrial regulations and similar to that of other equipment manufacturing	COD, P(?), -

Table 8.14: Summary of Impacts in the Renewables B Scenario, 1990-2025

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
Total Energy Consumption	**Electricity**			80 PJ from National Grid		19 PJ	
	Gas			338 PJ Natural Gas			
	Oil			331 PJ			
	Solid Fuel			6.8 PJ		25 PJ	
	Total			799 PJ		46 PJ	
1. Capital Cost	**£(1990) millions**	£80 to £813	C, P(H), Businesses and Households	Included in Fuel Costs		Included in Fuel Costs	
2. O&M Costs	**a. Fuel Costs**	Negligible		£1441to £3309	O, P(H), Households, Businesses in Council Area	Included in (a)	
	b. Other O&M Costs	Negligible		Included in Fuel Costs		Included in Fuel Costs	
3. Land Use, Landscape and Open Land				Possible use of agriculture land and/or wilderness areas for: a) Coal production b) Siting of new power stations c) New power lines	 COD, P(H), Tourists, Rural Communities; COD, P(E), Local Residents CD, P(L), Tourists, Local Communities	0.04 km2 for wind turbine foundations and access roads, 250,000 m2 roof space, 30 small engine houses	COD, P(H), Rural Communities inside and/or outside Council Area
4. Noise				Explosive noise from Oil surveying, Significant noise from coal mining and preparation	C, P(L), Costal Settlements, COD, P(H), Tourists, Rural Communities	Careful siting of turbines needed, some but minimal noise from extra traffic and engines	COD, P(H), Rural Communities inside and/or outside Council Area,
5. Visual Intrusion				Oil and Gas rigs visible from shoreline, Scarred landscape from coal mining, Transmission Pylons, Power Plants	COD, P(L), Tourists, Costal Settlements, COD, P(H), Tourists, Rural Communities, COD, P(?), Tourists, Rural Communities, COD, P(H), Tourists, Rural Communities	Some can be minimised with careful siting, and education programme	COD, P(?), Residents near sites

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
6. Transport	a. Power Transmission			Power Plants often need to be located near significant sources of water - power lines needed	COD, P(?), Residents along route	Grid lines needed from wind turbine sites to city	O, P(?), Rural Communities, Tourists outside Council Area
	b. Other Transport			Increased road transport to transport coal and oil	COD, P(H), Tourists, Rural Communities	Transportation of waste to plant of forestry residue	O, P(H), Local Residents
7. Health and Safety	a. Hazardous Materials					Manufacture of PV can involve the use of hazardous materials: dioborane, silane, silicon tetraflouride gases, cadmium, tellurium, copper and indium	M, P(L), Manufacturing Staff
	b. Ionising Radiation			Low rates from radio-active sourced nuclear tools used in oil and gas production, Risk of leaks from Nuclear plants	CODA, P(?), Workers;. ODA, P(L), depends on size of accident/leak - Workers, Local Communities to Continental		
	c. Other Risks	reduction of sick building syndrome	O, P(?), Businesses, Workers	Risks from dust, particulates, noise, methane explosions, tunnel collapse from coal mining and preparation	COD, P(H), Workers	Fire risk from stored dry straw. Storage of wood chips can lead to spore release which in a confined space, represents a health hazard. - Prolonged exposure can lead to Farmer's lung. Controlled by wearing face masks	O, P(L), Rural Communities inside and/or outside Council Area, O. P(L), Project Workers
8. Ecology				Disturbance from large projects on greenfield sites, marine life disturbed by seismic oil surveys, clearance of land to construct pylons	COD, P(H), -; C, P(L), Fishermen; COD, P(E), Tourism, Rural Communities	V. little damage with careful siting of projects, slight influence on mircoclimate below and behind wind turbines	O, P(L), -
9. Job Creation/Loss						Employment of local labour force in construction and maintenance	COD, P(?), Rural Communities and Local Communities

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
10. Liveability of Urban and Rural Areas	**a. Security**			Cost of providing extra security over and above that supplied by the plant owners	ODA, P(?), Nat. Gov.	Income for rural economies, security of supply, cost of energy not vulnerable to fluctuations as determined by capital costs, more jobs, less reliance on imports esp. if use UK products, Nat. Gov. looses tax revenue	COD, P(?), Rural Communities near site ; O, P(L), Residents. O, P(L), Nation
	b. Electromagnetic Interference					Not usually a problem, similar to that of static buildings	O, P(L), Rural Communities near site
	c. Recreation			Surface subsidence, changes to familiar scenery. Some impact on comfort and amenity	ODA, P(H), Tourists, Rural Communities		
	d. Odours and Smells					Specialist waste combustion can emit unpleasant odours - but can be minimised	O, P(E), Local Residents
	e. Building Quality	Increased levels of comfort, increased levels of lighting	O, P(H), Employees and Households				
11. Water Conservation and Quality	**a.Water Usage**					Some but low - CHP engine cooling water make up	O, P(H), -
	b. Water Quality			225 tonnes of oil spilt due to oil production, 5965 tonnes discharged on drill cuttings and 4850 tonnes with produced water. Current regs limit oil content of water to 40ppm, also pipeline leaks	CODA, P(H), -		
	c. Groundwater			Potential contamination from organic compounds and metals released during coal gasification. Soluble salts and phenolic compounds in the ash and char remains	CODA, P(?), -		

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
11. Water Conservation and Quality co ntinued....	**d. Drainage Patterns**			changes to water drainage patterns due to subsidence leading to changes in both surface topography and underlying strata	CODA, P(?), -		
12. Resources	**a. Natural Resources**			Depletion of Oil, Gas, Coal and Uranium Reserves	OA, P(100), -		
	b. Infrastructure/ Man-made Resources			Cost to the government and/or local authority of providing additional infrastructure when new power plants are built varies depending on local circumstances	COA, P(H), Nation and/or Local Communities		
13. Greenhouse Gas Emissions	**a. Carbon Dioxide**	Used as blowing agent for some foamed plastic insulation materials. Some releases during production	M, P(H), -	66 million tonnes + emissions from gas flaring, leakages, and gas used as part of the oil production process	COA, P(H), -		
	b. Nitrogen Oxides			120 million tonnes + emissions from gas flaring, leakages, and gas used as part of the oil production process	COA, P(H), -		
	c. Methane			6000 tonnes+ small amounts from gas flaring, leakages, and gas used as part of the oil production process	COA, P(H), -		
	d. CFCs	CFCs used as blowing agents in the production of some foamed plastic insulation materials. HFCs and CO2 also used.	M, P(H), -				

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
14. Air Quality	**a. Sulphur Dioxide**			132 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 260 thousand tonnes locally	COA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	b. Nitrogen Oxides			41thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 79 thousand tonnes locally	COA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	c. Carbon Monoxide			19 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 8.6 thousand tonnes locally	COA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	d. VOC			2.7 thousand tonnes nationally + emissions from gas flaring, leakages, and gas used as part of the oil production process + 3.3 thousand tonnes locally	COA, P(H), Residents near project sites, O, P(H), Residents of Council Area and of Neighbouring Areas		
	e. Particulates			Airborne dust can be combated, 0.02% of coal lost during transport loading, coal dust from rail transport. , 7.9 tonnes nationally 7.6 tonnes locally from burning fossil fuels	COA, P(H), Residents near project sites , O, P(H), Residents of Council Area and of Neighbouring Areas		
	f. Thermal Emissions			some but low	COD, P(L), Local Communities	Some but majority used to produce hot water	O, P(H), Residents near site
	g. Other Emissions			potential leakage of 300gms/GJ H2 and H2S	COD, P(?), Local Communities	Low levels of dioxins, some acidic gases from burning waste.	O, P(H), Residents near site

		Energy Efficiency		Fossil Fuels and Nuclear Fuels		Renewables	
15. Land and Soil Quality	**a. Heavy Metals**			6 to 9 g/GJ from coal preparation processes	O, P(H), Workers, Local Communities, Wider	Trace from waste and biomass, some from PV which need careful handling when decommission -ing	O, P(H), Residents near site, D, P(L), Workers
	b. Soil			opencast mining - severe soil disturbance, reduces soil fertility, problems of compaction	CODA, P(H), Local Communities		
	c. Solid and Liquid Waste			Oil mud spills from drilling, spoils from coal mining and preparation, radio-active material from nuclear power plants	CO, P(H), -; CO, P(H), Local Communities; CODA, P(H), Local Communities		
	d. Other Pollutants					Minor amounts of oil from greasing turbines, Some pollution from manufacturing process but within industrial regulations and similar to that of other equipment manufacturing	COD, P(?), -

Chapter Nine

CONCLUSIONS AND FUTURE WORK

9.1 CONCLUSIONS

Many different definitions and interpretations of the term "sustainable development" were found to exist. However, there is a general agreement that current patterns of energy use are unsustainable in the long-term. High dependence on the burning of fossil fuels, which are a finite resource and result in the emission of air pollutants amongst other environmental impacts, cannot continue indefinitely, particularly as world-wide energy demand is increasing year on year, with continued economic growth. Agenda 21 stressed the importance of taking action at all levels, from international to national to local and individual, and highlighted the role of Local Authorities in this process.

Milton Keynes is one of the many Local Authorities in the European Union, and elsewhere, that have taken up this challenge. The city has a past record of implementing innovative policies and projects with regards to energy, such as the HomeWorld, EnergyWorld and FutureWorld exhibitions, and the requirement for new housing to be energy efficient. However, a comparison of Milton Keynes with a number of other UK cities showed that energy consumption per capita in the city is close to the average for the UK and higher than that of London and Newcastle. This is largely as a result of much higher than average per capita energy demand for transport, which was over twice that of Newcastle.

There was found to be a wide range of options available to Milton Keynes for reducing the impact of its energy consumption, including switching to less polluting fuel sources, using renewable energy, introducing energy efficiency measures, improving energy management and inducing behaviour changes such as reducing the need to travel. There is scope for energy to be produced locally from wind, solar, municipal waste incineration, landfill gas, and park and forestry residues. Additionally, economically-viable savings from energy efficiency and energy management measures in the order of

20% can be achieved in the industrial and services sectors. Savings in the order of 30% can be achieved in the domestic and transport sectors.

The problem confronting Milton Keynes, as well as many other Local Authorities across the EU, is which combination of these options will have the least economic, environmental and social impacts, i.e. be most effective in moving energy consumption patterns towards sustainability. To ensure that energy policies, plans and programmes (PPPs) meet the objectives of sustainable development the EC requires a Strategic Environmental Assessment (SEA) to be carried out on all energy policies, plans and programmes. However, to date, there is very little experience within the energy field of full Sustainability Assessment of policies. Those few that have been carried out concentrate on a narrow range of impacts. Outside the energy field, SEA techniques have been more widely used and in a few cases adapted to cover economic and social impacts as well as environmental impacts. This is particularly the case in the UK for the area of land-use planning and, to a lesser extent, for transport planning. Recent emphasis in these areas has been on the assessment process and not on the methodologies used.

The Sustainability Assessment methodology developed in this thesis was designed to fulfil the need for a comprehensive assessment framework aimed specifically at assessing the sustainability of energy policies at the city-scale. The assessment process follows similar steps to those typically used for Environmental Assessment and Strategic Environmental Assessment, but a greater emphasis has been placed on the appraisal techniques and the presentation of the information on the impacts than is usually the case. The methodology uses an impacts matrix which is flexible enough to handle both quantitative and qualitative data, in the recognition that often it is not possible to quantify every impact. Information on the probability of occurrence (or risk) and the timescale of the impact is presented in the matrix, alongside information on who is likely to be affected by each impact and the quality of the data presented. Energy demand and emissions data were quantified using an energy model.

The methodology was initially tested "in the laboratory" using a series of energy strategies designed to incorporate a wide range of the energy technologies and reduction measures available to Milton Keynes. These strategies were modelled and appraised.

The choice of strategy for the city was found to depend on the importance placed by the decision makers on each of the possible selection criteria. No one strategy stood out as being the obvious choice. The Green Strategy could, depending on whether actual costs reflect the top or the bottom of the range of possible monetary costs that were modelled, cost a lot of money to implement or could save the Local Authority, residents and businesses substantial amounts of money whilst still reducing the impacts of energy consumption.

The methodology was then "field tested" with Milton Keynes Energy Agency. Two energy strategies were assessed – one based on achieving a target of 10% of electricity to be generated from renewable sources by 2010, and the other based on achieving zero growth in carbon dioxide emissions. These were compared with a baseline Current Trends Continued scenario. In the process of modelling and assessing the first of these strategies, it was found that zero growth in carbon dioxide emissions could be achieved through the introduction of renewables alone. It was also found that Milton Keynes energy consumption could grow by over 30% over the next 25 years if current trends in energy demand do not change (CTC00), resulting in an increase in carbon dioxide emissions of 25%. This estimate of growth is based on relatively conservative estimates of economic growth for the Borough. The level of renewables assumed in the Renewables A scenario is not sufficient to achieve the 10% target set by Government for 2010 by relying on local systems alone. However, it remains unclear what role large-scale schemes outside the immediate area of Milton Keynes will play in achieving this target. The Renewables B scenario resulted in a stabilising of carbon dioxide emissions below current levels and more than met the target of 10% of electricity from renewable sources by 2010.

The laboratory and field tests of the methodology provided some useful insights into the suitability of the assessment framework and appraisal techniques for assessing local energy policies, plans and programmes, as well as some ideas for improvements.

With regard to the energy model, the data used as input to the model requires to be updated regularly if the output from the model is to be used as part of an assessment of different future policy options for the city. A regularly updated model would also prove a useful monitoring tool. At present the most time-consuming part of setting up the

DREAM model for a city is the data collection process. The model input requirements need to be reduced, so that it can be set up and updated to give reasonably reliable energy and emissions figures for a Local Authority quickly and easily. This would also reduce the number of assumptions required to be made when modelling an energy strategy. Obtaining data of sufficient quality on historical energy demand to validate the model was also a problem. Government legislation is probably required to ensure that the energy distribution companies make this data available. Despite these limitations, MKEA were interested in continued use of the energy model and the National Energy Foundation (members of MKEA) has expressed interest in purchasing a licence to use DREAM to help other Local Authorities and Energy Agencies to assess their energy strategies.

Feedback from MKEA on the impact matrices was generally encouraging. MKEA found the matrices useful, particularly the fuel and capital costs elements incorporated into them. However, the need for supporting impact statements was highlighted. It was not possible to evaluate many of the social and environmental impacts of each of the scenarios in sufficient depth to enable a clear distinction to be made between the scenarios. This is partly due to the use of generic qualitative rather than specific quantitative data, and partly a result of some detail being lost during the process of summarising qualitative data into short sentences suitable for inclusion in the impacts database and in the matrices. The accompanying impact statements can help overcome some of these limitations. However, despite the lack of detailed information on some of the impacts, the methodology helped highlight some important differences between the scenarios such as the LA21 Scenario contributing increased amounts of greenhouse gas emissions to global warming over the Current Trends Continued Scenario.

A key to the methodology being fast and reliable is the availability of a comprehensive database listing the impacts of as many technologies and policies as possible. The use of databases set up for life-cycle analysis (LCA) software was considered, but these were found to be too detailed for strategy level analysis. Many were also limited in the number of different impacts assessed and few considered social impacts. The beginnings of a suitable database were created for the assessments done as part of this project. However, much of the information needed on the social impacts of the PPPs was not available and much of the impact information available was not of sufficient detail to enable the differences between scenarios to be distinguished.

The assessment framework in general was found to be useful as a decision aid and it was felt by MKEA that it would help improve the policy-making process.

9.2 Future Work

In order for the methodology to be of use to Local Authority decision makers, it needs to provide a way of assessing with speed and reliability the scenarios derived from number of strategies. The methodology described in this report has the potential to fulfil these needs. However, before assessment of scenarios can be achieved within a reasonable timescale it requires further work, such as the creation of a more comprehensive and searchable database, and improved links between the model and the impact assessment to reduce the amount of data manipulation required.

At present, once a list of the impacts associated with each technology or policy within a scenario has been obtained from the database, a summary sheet must be created by hand. This requires an individual, or preferably a small team, to go through the large tables summarising for each of the evaluation criteria the total impact from all the PPPs making up the scenario. This can be time consuming and has potential for bias to creep into the decision through the emphasis of some impacts over others. There is no obvious solution to this problem due to the qualitative nature of some of the impact data. One solution could be to use contingent valuation techniques to produce quantitative data in monetary terms so that the impacts can be easily summed. However, use of these techniques can be time consuming and costly, and there are those who object to these techniques on philosophical grounds.

Consideration should also be given to the discounting of impacts, to take into account the tendency of impacts to occur later rather than sooner. This would also make a fairer comparison between those impacts with a monetary value and those without.

This method of assessment was partly chosen because it follows closely with Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA) methodologies already known and used by many local authorities. It should be therefore easily adopted by local authorities. However, the ease of use by local authorities has not yet been fully tested. Ideally, the methodology would be tested with a variety of people from different roles within the local authority, including councillors, strategists, planners and other council officers, as well as members of community groups and the general public. This would ensure that the method can be applied and understood by both those making the decisions and those whom the decisions would affect. If members of the community understand how and why a decision was made they are more likely to support the policies, plans and programmes resulting from that decision and will feel better able to participate in the decision-making processes.

PAGE

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AS ORIGINAL

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